UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Computational Biology and Complex Systems Research Group

CMCiB Comparative Medicine & Bioimage Centre of Catalonia

IGTP Germans Trias i Pujol Research Institute

Daily report 27-05-2020

# Analysis and prediction of COVID-19 for EU-EFTA-UK and other countries



Contact: clara.prats@upc.edu

*With the financial support of:* MINISTERIO DE CIENCIA E INNOVACIÓN "la Caixa"

## Foreword

The present report aims to provide a comprehensive picture of the **pandemic situation of COVID-19** in the EU countries, and to be able to foresee the situation in the next coming days.

We employ an **empirical model**, verified with the evolution of the number of confirmed cases in previous countries where the epidemic is close to conclude, including all provinces of China. The model does not pretend to interpret the causes of the evolution of the cases but to permit the **evaluation of the quality of control measures made in each state** and a **short-term prediction of trends**. Note, however, that the effects of the measures' control that start on a given day are not observed until approximately 7-10 days later.

The model and predictions are based on two parameters that are daily fitted to available data:

- ✓ *a*: the velocity at which spreading specific rate slows down; the higher the value, the better the control.
- ✓ *K*: the final number of expected cumulated cases, which cannot be evaluated at the initial stages because growth is still exponential.

We show an individual report with 8 graphs and a table with the **short-term predictions** for different countries and regions. We are adjusting the model to **countries and regions** with at least 4 days with more than 100 confirmed cases and a current load over 200 cases. The **predicted period** of a country depends on the number of datapoints over this 100 cases threshold, and is of 5 days for those that have reported more than 100 cumulated cases for 10 consecutive days or more. For short-term predictions, we assign higher weight to last 3 points in the fittings, so that changes are rapidly captured by the model. The whole methodology employed in the inform is explained in the last pages of this document.

In addition to the individual reports, the reader will find an initial dashboard with a brief analysis of the situation in EU-EFTA-UK countries, some summary figures and tables as well as **long-term predictions** for some of them, when possible. These long-term predictions are evaluated without different weights to data-points. We also discuss a specific issue every day.

Martí Català
Pere-Joan Cardona, PhD
*Comparative Medicine and Bioimage Centre of Catalonia; Institute for Health Science Research Germans Trias i Pujol*

Clara Prats, PhD
Sergio Alonso, PhD
Enric Álvarez, PhD
Miquel Marchena
David Conesa
Daniel López, PhD
*Computational Biology and Complex Systems; Universitat Politècnica de Catalunya - BarcelonaTech*

**With the collaboration of:** Guillem Álvarez, Oriol Bertomeu, Laura Dot, Lavínia Hriscu, Helena Kirchner, Daniel Molinuevo, Pablo Palacios, Sergi Pradas, David Rovira, Xavier Simó, Tomás Urdiales

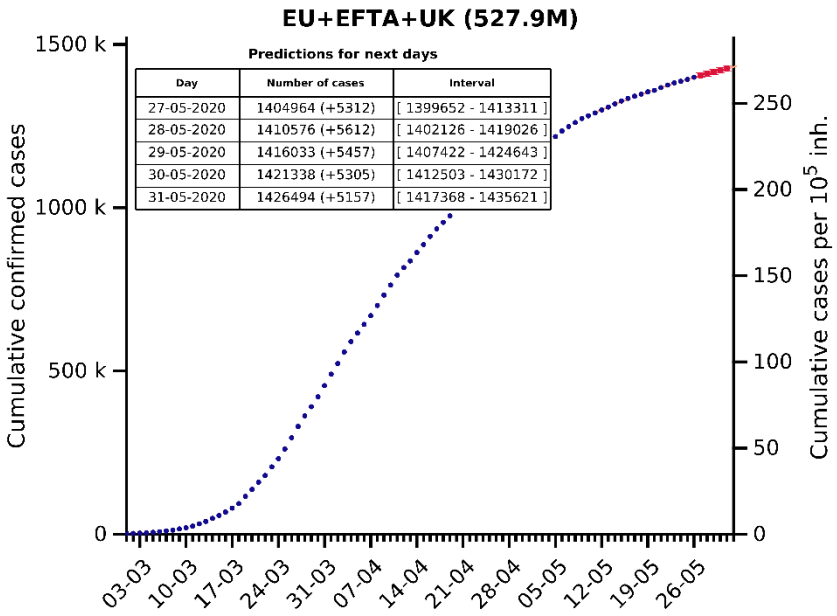
PJC and MC received funding from "la Caixa" Foundation (ID 100010434), under agreement LCF/PR/GN17/50300003; CP, DL, SA, MC, received funding from Ministerio de Ciencia, Innovación y Universidades and FEDER, with the project PGC2018-095456-B-I00;

**Disclaimer: These reports have been written by declared authors, who fully assume their content. They are submitted daily to the European Commission, but this body does not necessarily share their analyses, discussions and conclusions.**

# (0) Executive summary – Dashboard

## Global EU+EFTA+UK trends and needs

At this moment, most EU+EFTA+UK countries are in a very satisfactory epidemiological situation. The weeks with the worst incidences have been left behind. Sweden seems to be the only country that is resisting to enter a clear improvement stage. The UK currently reports a number of daily new cases per 100,000 inhabitants similar to that of Sweden, but it is following a decreasing dynamic. Nevertheless, after a few days below 2,500 daily new cases, UK has grown again until the level of 4,000. We should wait for a few days in order to check if this is an isolated increase caused by a delay in reporting or a worsening's symptom.



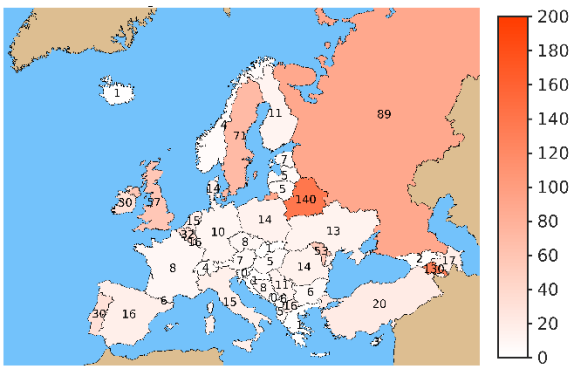

Among the countries that have had a considerable impact, it should be noted that some have stopped declining, such as Portugal, Poland and the Czech Republic. They remain at a level of new cases quite stable. It is really expected that many other countries will end up having this type of behavior. In fact, as we discussed yesterday, it is very difficult to expect a total decrease in the number of cases down to zero. At this moment, it is only observed in Iceland. A situation like the one in Austria, where a very low value of new cases remains, can be considered satisfactory

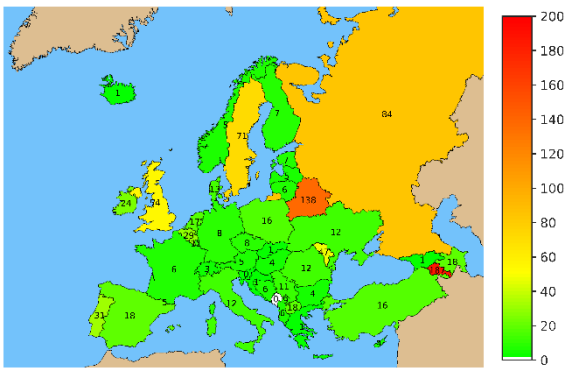
The analysis is focused on discussing **the triggering of secondary outbreaks in countries with an apparent control of the epidemic**.

## Trends for specific countries

**Portugal** and **Netherlands** have a $\rho_7$ around 1, with a still intermediate level of 14-day attack rate. They should be watched out for a few days to ensure that control situation is not lost. **Sweden** remains at $\rho_7 \approx 1$ and with high 14-day attack rate. It is therefore at moderate-high risk, still ($EPG_{REP} \approx 70$). There are other countries at this $\rho_7$ level, but with a low 14-day attack rate that ensures low risk, by the moment.

The map in the left shows current **$A_{14}$**. The map in the right shows current **EPG**.



## Situation and trends per country

Table of current situation in EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. Last column (**$EPG_{EST}$**) indicates EPG assessed with **estimated real 14-day attack rate** (see report from 22/04 for details). **$EPG_{REP}$** is calculated with **data reported by countries**. $EPG_{REP}$ and $EPG_{EST}$ **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively.

| | Reported data | | | | | | | | Indexes | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | Cumulative cases | Attack rate /$10^5$ inh. | Cumulative deaths | Mortality /$10^5$ inh. | Active cases (last 14 days) | 14-day attack rate /$10^5$ inh. | Estimated active cases (last 14 days) | Estimated 14-day attack rate /$10^5$ inh. | $\rho_7$ [1] | $EPG_{REP}$ [2] | $EPG_{EST}$ [3] |
| United Kingdom | 265,227 | 399.2 | 37,048 | 55.8 | 38,764 | 58.3 | 566,424 | 834.4 | 0.95 | 55 | 789 |
| Spain | 236,259 | 509.8 | 27,117 | 58.5 | 8,007 | 17.3 | 92,973 | 197.7 | 1.15 | 20 | 227 |
| Italy | 230,555 | 387.9 | 32,955 | 55.5 | 9,339 | 15.7 | 136,296 | 225.4 | 0.81 | 13 | 182 |
| Germany | 179,364 | 219.0 | 8,349 | 10.2 | 8,058 | 9.8 | 39,094 | 46.7 | 0.85 | 8 | 40 |
| France | 145,555 | 224.9 | 28,530 | 44.1 | 5,328 | 8.2 | 106,806 | 163.6 | 0.78 | 6 | 128 |
| Belgium | 57,455 | 505.9 | 9,334 | 82.2 | 3,676 | 32.4 | 61,942 | 534.5 | 0.90 | 29 | 482 |
| Netherlands | 45,578 | 268.3 | 5,856 | 34.5 | 2,594 | 15.3 | 33,609 | 196.1 | 1.09 | 17 | 214 |
| Sweden | 34,440 | 350.1 | 4,125 | 41.9 | 7,168 | 72.9 | 93,289 | 923.7 | 1.00 | 73 | 928 |
| Portugal | 31,007 | 298.9 | 1,342 | 12.9 | 3,094 | 29.8 | 13,975 | 137.1 | 1.03 | 31 | 141 |
| Switzerland | 30,678 | 358.0 | 1,647 | 19.2 | 381 | 4.4 | 2,061 | 23.8 | 0.64 | 3 | 15 |
| Ireland | 24,735 | 523.4 | 1,615 | 34.2 | 1,493 | 31.6 | 9,673 | 195.9 | 0.79 | 25 | 155 |
| Poland | 22,074 | 57.7 | 1,024 | 2.7 | 5,153 | 13.5 | 27,758 | 73.3 | 1.15 | 16 | 84 |
| Romania | 18,429 | 93.2 | 1,210 | 6.1 | 2,651 | 13.4 | 18,374 | 95.5 | 0.90 | 12 | 86 |
| Austria | 16,497 | 189.4 | 643 | 7.4 | 587 | 6.7 | 2,362 | 26.2 | 0.83 | 6 | 22 |
| Denmark | 11,428 | 200.1 | 563 | 9.9 | 837 | 14.7 | 4,215 | 72.8 | 0.91 | 13 | 66 |
| Czech Republic | 9,050 | 85.3 | 317 | 3.0 | 829 | 7.8 | 3,116 | 29.1 | 1.04 | 8 | 30 |
| Norway | 8,364 | 155.8 | 235 | 4.4 | 229 | 4.3 | 657 | 12.1 | 1.28 | 5 | 16 |
| Finland | 6,628 | 120.4 | 312 | 5.7 | 625 | 11.4 | 3,135 | 56.6 | 0.62 | 7 | 35 |
| Luxembourg | 3,995 | 693.6 | 110 | 19.1 | 101 | 17.5 | 277 | 44.3 | 0.68 | 12 | 30 |
| Hungary | 3,793 | 38.9 | 505 | 5.2 | 452 | 4.6 | 6,353 | 65.8 | 0.83 | 4 | 54 |
| Greece | 2,892 | 25.9 | 173 | 1.5 | 148 | 1.3 | 904 | 8.7 | 0.68 | 1 | 6 |
| Bulgaria | 2,460 | 34.5 | 133 | 1.9 | 437 | 6.1 | 2,509 | 36.1 | 0.66 | 4 | 24 |
| Croatia | 2,244 | 53.3 | 101 | 2.4 | 37 | 0.9 | 174 | 4.2 | 0.88 | 1 | 4 |
| Estonia | 1,834 | 139.8 | 65 | 5.0 | 88 | 6.7 | NA | NA | 1.01 | 7 | NA |
| Iceland | 1,804 | 495.3 | 10 | 2.7 | 3 | 0.8 | NA | NA | 0.86 | 1 | NA |
| Lithuania | 1,639 | 56.4 | 65 | 2.2 | 148 | 5.1 | NA | NA | 1.17 | 6 | NA |
| Slovakia | 1,513 | 27.8 | 28 | 0.5 | 48 | 0.9 | NA | NA | 1.46 | 1 | NA |
| Slovenia | 1,469 | 70.7 | 106 | 5.1 | 6 | 0.3 | 45 | 2.2 | 0.50 | 0 | 1 |
| Latvia | 1,053 | 53.4 | 22 | 1.1 | 103 | 5.2 | NA | NA | 0.88 | 5 | NA |
| Cyprus | 939 | 80.3 | 17 | 1.5 | 36 | 3.1 | NA | NA | 1.41 | 4 | NA |
| Malta | 611 | 142.4 | 6 | 1.4 | 108 | 25.2 | NA | NA | NA | NA | NA |
| Liechtenstein | 83 | 215.3 | 1 | 2.6 | 0 | 0.0 | NA | NA | NA | NA | NA |
| | Scale | | | | | | | | | | |
| | Worst | Worst | Worst | Worst | Worst | Worst | Worst | Worst | 2.0 | 100 | 1000 |
| | Best | Best | Best | Best | Best | Best | Best | Best | 0.0 | 0 | 0 |

[1] $\rho_7$ is the average of 7 consecutive ρ, but can still fluctuate. [2,3] EPG stands for Effective Growth Potential. $EPG_{REP}$ is obtained by multiplying attack rate of last 14 days per $10^5$ inhabitants (i.e. density of cases) by $\rho_7$ (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). $EPG_{EST}$ is obtained by multiplying estimated real attack rate of last 14 days per $10^5$ inhabitants by $\rho_7$.

## Highlights for countries with highest number of reported cases

- ✓ Spain is reviewing all historical data and reports a decrease in deaths as a consequence of this revision. There are also a few inconsistences in reported cases that will persist until complete revision is finished.
- ✓ Italy, Germany and France maintain the trends of previous days.
- ✓ UK is still at moderate risk, according to $EPG_{REP}$, but the other countries maintain their situation of low risk.

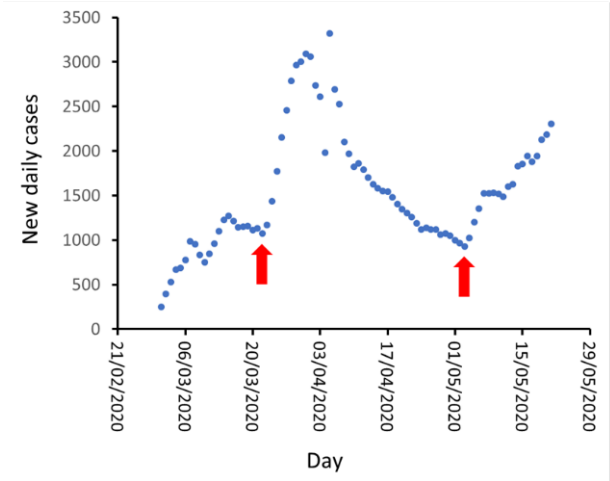
## Analysis: What if the epidemics is not controlled? The STOP AND GO scenario of a highly clustered propagation.

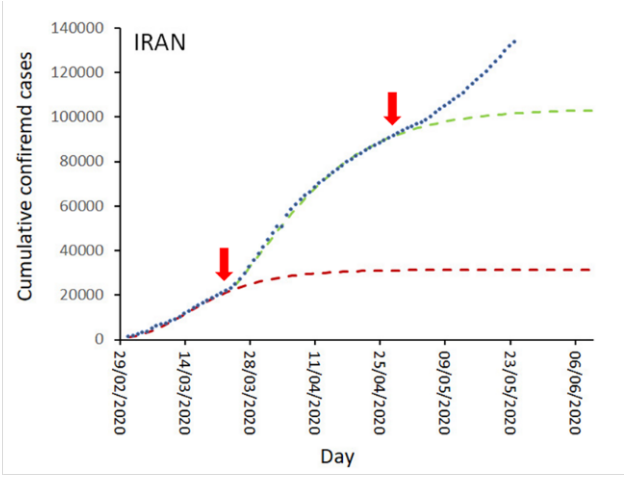
Yesterday we discussed how some countries are successfully controlling the epidemic. Unfortunately, this do not guarantee that the problem has been overcome. We expect that, in most countries, there will always be people with the potential to transmit the disease. **The conditions required to completely eliminate the virus are complicated:**

1) First, **no new case, not a single one, must be detected in 3-4 weeks**. Given that detection rates are close to 10% in most European countries, any case detected probably means 10 more undetected with a low level of symptoms that can propagate the disease under the radar. 4 weeks is the largest time scale of the disease cycle (infection-mild symptoms-serious symptoms-complications-deaths)
2) After 3-4 weeks without cases in a given region, **a full control and isolation of this population from other areas is needed**. An area where there is literally no active case together with an area where there is low incidence is just one big area with slightly lower incidence.
3) And still, even if there are no new cases detected and complete isolation from other areas with detected cases, the fact that **people with low or no symptoms are close to 50% of the total makes full elimination difficult**. The reason is that the presence of infection chains of asymptomatic cases without detection is very likely.

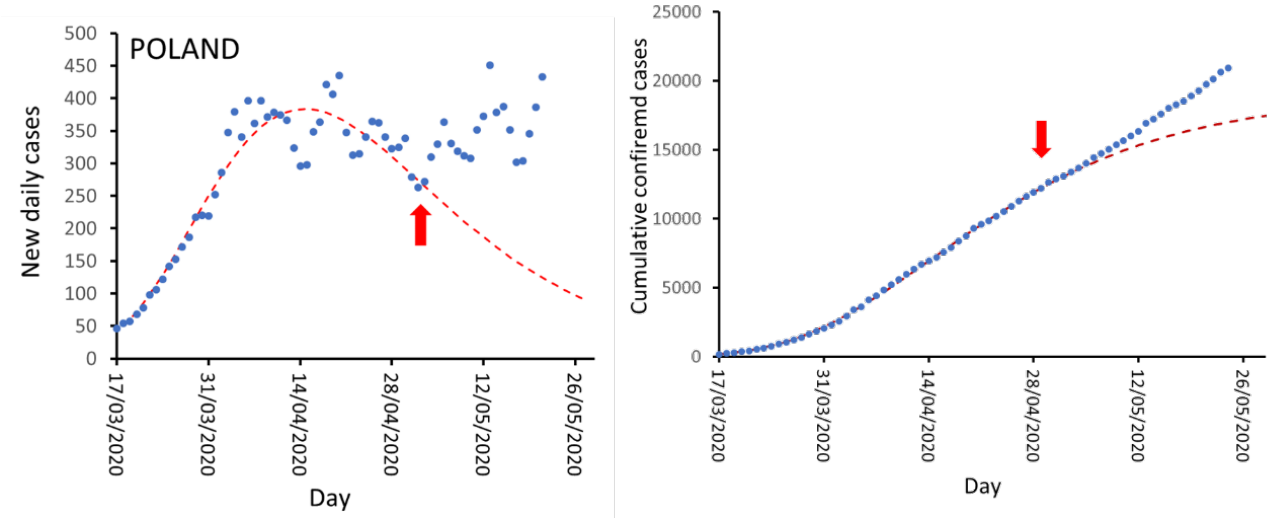
In addition, we must keep in mind that there is a large number of susceptible people. Therefore, it is a rather straightforward conclusion that, even in countries which seem to have the epidemics under control, the risk for a secondary outbreak is not zero. The epidemiological evolution in some countries shows us precisely this risk we all face.

**Let us look at the case of Iran,** for example, as one of the first countries affected by SARS-CoV-2 outside of East Asia. **The country initially managed to contain the spread of the disease satisfactorily**, but by the end of March **they had secondary outbreak** that was not controlled and the epidemics grew again. They regained control, but then again in late April**, the epidemics started to grow back again for the third time**. We can understand better this description with the help of the graphs below. On the left, we represent the number of daily new cases. We observe how, at the points indicated by the red arrows, the number of new cases grew again significantly. In the figure on the right we represent the cumulative number of cases. We first adjust a Gomperz function (brown) at the beginning of the epidemic and a second function from the end of March (green). **We can see how effectively the behavior can be correctly described as the succession of three epidemic growths**.



The bottom line is that a controlled situation can become uncontrollable, we have not yet solved the problem, we must maintain effort and vigilance. However, Iran is not the only country that shows this type of stop and go behavior. Below we show the same plots for Poland.




We observe how the evolution of the epidemics seems to be under control at the end of April but at the point indicated by the red arrow, the number of new cases grows again. The graph of accumulated cases has similarities with the behavior of Iran. At this moment, there is a linear growth in the total number of cases in Poland, and there is no indication that this linear growth of accumulated number of cases is going to decline in the short term. We must remember that a linear growth in cumulated cases means a reproductive number close to 1 with roughly a constant number of new cases. **The difference with other countries where the situation is under control is that this constant number of new cases is quite high**. Similar behaviors are found in other countries. A typical example is Sweden who has a rather constant number of cases and deaths per day. If we look at the history of the death toll in Sweden we realize that the last days of statistics are not useful since new cases are reported and placed at the day they were detected. Discounting them we observe a constant number of roughly a very slowly decreasing number of new deaths from 60 to 40 during 3 weeks.

It is very interesting to see how in most countries we can describe the evolution of the pandemic using a Gompertz model, and rather surprising to check how in some countries the proper way to describe the dynamics of the pandemic requires the use of **two or three consecutive adjustments of the Gompertz function**. We consider that this clearly unveils the **presence of successive and independent growths or outbreaks**. Recent reports on the dispersion of the epidemics point out to a propagation where clustering effects are large. If this were to be the case, we expect this pattern of behavior to be repeated everywhere where the level of back ground activity of the virus is not very low.

Most likely, the pandemic will not be considered controlled until we have vaccines. Until then, we will have to keep up the effort on the part of the population and the surveillance work on the part of the health authorities. In future reports we will deal with on the relevance of the clustering parameter on this type of STOP AND GO scenario and its socio-economic impact.

## Situation and trends in other countries

**Table** of current situation in a sample of non-EU countries. Colour scale is relative except when indicated, this means that it is applied independently to each column, and distinguishes best (green) form worst (red) situations according to each of the variables. $EPG_{REP}$ and $EPG_{EST}$ **cannot be compared between them** because scales are different, but can be independently used for estimating risk of countries according to reported or estimated real situation, respectively.

| | Reported data | | | | | | | | Indexes | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | Cumulative cases | Attack rate /$10^5$ inh. | Cumulative deaths | Mortality /$10^5$ inh. | Active cases (last 14 days) | 14-day attack rate /$10^5$ inh. | Estimated active cases (last 14 days) | Estimated 14-day attack rate /$10^5$ inh. | $\rho_7$ [1] | $EPG_{REP}$ [2] | $EPG_{EST}$ [3] |
| United States of America | 1.681.212 | 507,9 | 98.916 | 29,9 | 311.248 | 94,0 | 1.979.651 | 598,1 | 0,97 | 91 | 581 |
| Brazil | 391.222 | 184,1 | 24.512 | 11,5 | 213.633 | 100,5 | 1.579.438 | 743,1 | 1,24 | 124 | 918 |
| Russia | 362.342 | 248,3 | 3.807 | 2,6 | 130.099 | 89,1 | NA | NA | 0,94 | 84 | NA |
| India | 151.767 | 11,2 | 4.337 | 0,3 | 77.486 | 5,7 | 268.088 | 19,8 | 1,29 | 7 | 25 |
| Iran | 139.511 | 166,1 | 7.508 | 8,9 | 28.744 | 34,2 | 163.291 | 194,4 | 1,07 | 37 | 209 |
| Peru | 129.751 | 393,5 | 3.788 | 11,5 | 57.692 | 175,0 | 193.411 | 586,6 | 1,05 | 183 | 614 |
| Canada | 86.636 | 229,5 | 6.639 | 17,6 | 15.479 | 41,0 | 137.865 | 365,3 | 0,97 | 40 | 354 |
| Chile | 77.961 | 407,8 | 806 | 4,2 | 46.240 | 241,9 | 100.041 | 523,3 | 1,47 | 355 | 767 |
| Saudi Arabia | 76.726 | 220,4 | 411 | 1,2 | 33.801 | 97,1 | NA | NA | 0,99 | 97 | NA |
| Mexico | 74.560 | 57,8 | 8.134 | 6,3 | 36.236 | 28,1 | 517.876 | 401,7 | 1,20 | 34 | 482 |
| Pakistan | 59.151 | 26,8 | 1.225 | 0,6 | 24.815 | 11,2 | 58.380 | 26,4 | 1,14 | 13 | 30 |
| Qatar | 47.207 | 1.638,5 | 28 | 1,0 | 22.058 | 765,6 | NA | NA | 1,09 | 834 | NA |
| Belarus | 38.059 | 402,8 | 208 | 2,2 | 13.186 | 139,5 | NA | NA | 0,99 | 138 | NA |
| Ecuador | 37.355 | 211,7 | 3.203 | 18,2 | 6.936 | 39,3 | 74.283 | 421,0 | 0,89 | 35 | 375 |
| Argentina | 13.215 | 29,2 | 484 | 1,1 | 6.665 | 14,7 | 40.891 | 90,5 | 1,86 | 27 | 169 |
| | Scale | | | | | | | | | | |
| | Worst | Worst | Worst | Worst | Worst | Worst | Worst | Worst | 2,0 | 100 | 1000 |
| | Best | Best | Best | Best | Best | Best | Best | Best | 0,0 | 0 | 0 |

[1] $\rho_7$ is the average of 7 consecutive ρ, but can still fluctuate. [2,3] EPG stands for Effective Growth Potential. $EPG_{REP}$ is obtained by multiplying attack rate of last 14 days per $10^5$ inhabitants (i.e. density of cases) by $\rho_7$ (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). $EPG_{EST}$ is obtained by multiplying estimated real attack rate of last 14 days per $10^5$ inhabitants by $\rho_7$.

**Disclaimer:** estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

## Time indicators by country

These tables summarize a few time indicators for each country: time since 50 cases were reported, time interval between an attack rate of $1/10^5$ inhabitants and an attack rate of $10/10^5$ inhabitants, and time interval between attack rates of 10 to 100 per $10^5$ inhabitants (only for countries that have overtaken this threshold).

### EU+EFTA+UK countries

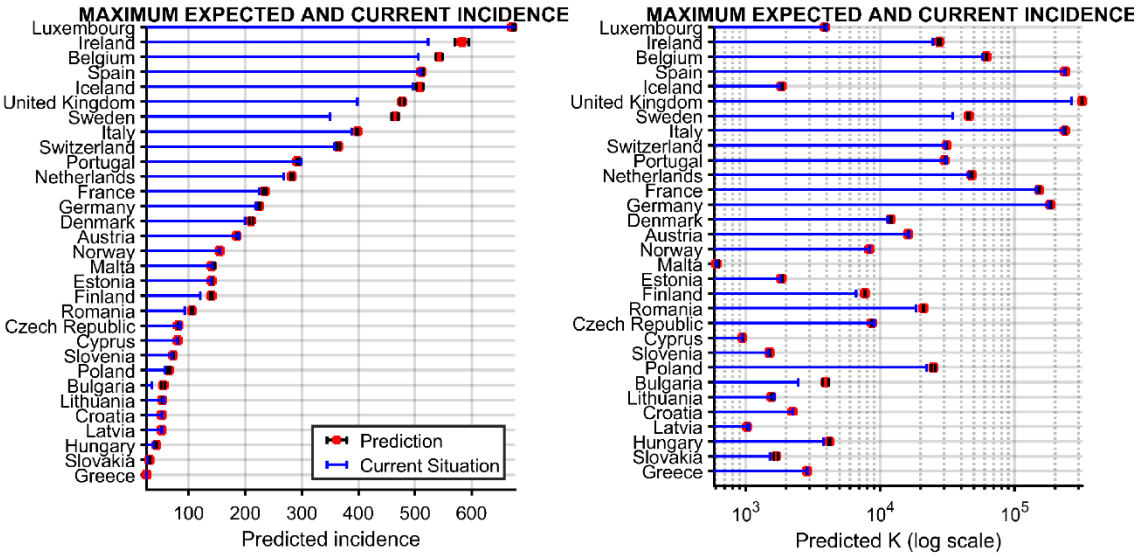
| Countries | Days since the first 100 cases | Time interval between 1 and 10 cases / $10^5$ inh. (days) | Time interval between 10 and 100 cases / $10^5$ inh. (days) |
|---|---|---|---|
| Italy | 94 | 11 | 16 |
| Germany | 88 | 12 | 17 |
| France | 87 | 10 | 20 |
| Spain | 87 | 8 | 12 |
| United Kingdom | 83 | 10 | 12 |
| Belgium | 82 | 11 | 14 |
| Netherlands | 82 | 11 | 20 |
| Sweden | 82 | 10 | 28 |
| Norway | 82 | 2 | 7 |
| Switzerland | 82 | 8 | 11 |
| Austria | 80 | 10 | 14 |
| Denmark | 79 | 4 | 30 |
| Czech Republic | 76 | 11 | NA |
| Finland | 76 | 12 | 46 |
| Greece | 76 | 18 | NA |
| Iceland | 76 | 5 | 15 |
| Portugal | 75 | 9 | 15 |
| Slovenia | 75 | 6 | NA |
| Estonia | 74 | 5 | 30 |
| Ireland | 74 | 8 | 18 |
| Poland | 74 | 17 | NA |
| Romania | 74 | 15 | NA |
| Luxembourg | 71 | 6 | 7 |
| Slovakia | 70 | 24 | NA |
| Bulgaria | 69 | 30 | NA |
| Croatia | 69 | 12 | NA |
| Hungary | 68 | 20 | NA |
| Latvia | 68 | 12 | NA |
| Lithuania | 67 | 9 | NA |
| Malta | 66 | 9 | 35 |
| Cyprus | 65 | 12 | NA |

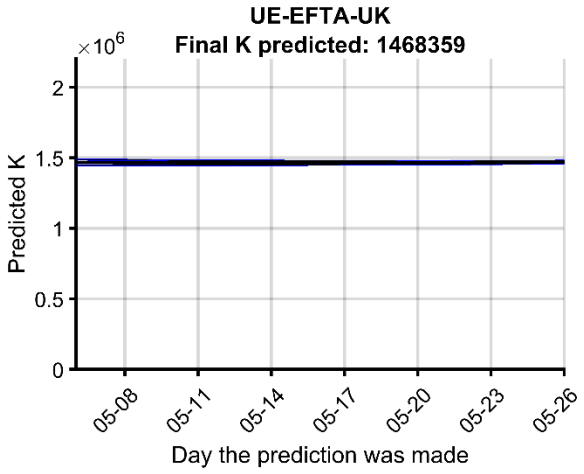
## Other countries

| Countries | Days since the first 100 cases | Time interval between 1 and 10 cases / $10^5$ inh. (days) | Time interval between 10 and 100 cases / $10^5$ inh. (days) |
|---|---|---|---|
| Iran | 91 | 11 | 42 |
| United States of America | 86 | 8 | 15 |
| Canada | 77 | 11 | 27 |
| Qatar | 77 | 3 | 31 |
| Brazil | 74 | 20 | 34 |
| Saudi Arabia | 73 | 21 | 29 |
| Chile | 72 | 13 | 36 |
| Pakistan | 72 | 35 | NA |
| India | 72 | 38 | NA |
| Russia | 71 | 15 | 24 |
| Peru | 71 | 18 | 22 |
| Ecuador | 71 | 10 | 30 |
| Mexico | 70 | 25 | NA |
| Argentina | 69 | 39 | NA |
| Belarus | 58 | 10 | 18 |

## Long-term predictions

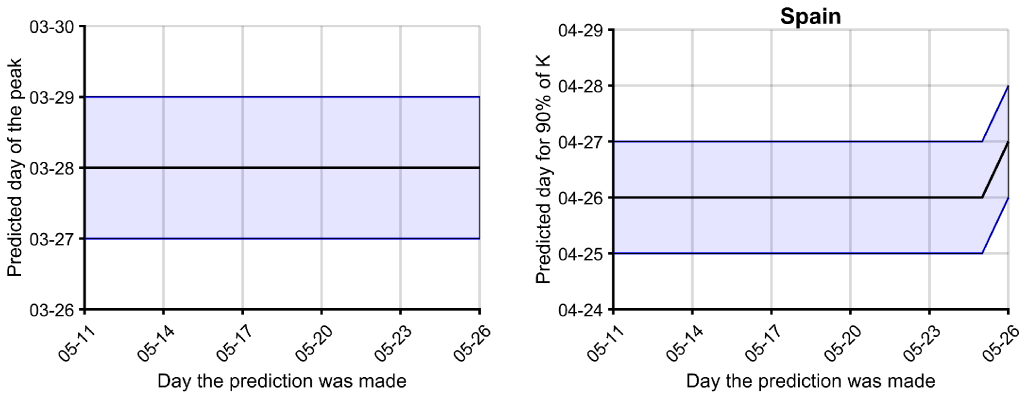
Evaluated with the **whole historical series**. See figure in the next page. Up-left: Predictions of maximum incidences per country (total final expected attack rate per $10^5$ inh.). Up-right: Predictions of maximum absolute number of cases per country (K, in log scale). Blue lines indicate current situation. Bottom-left: Time in which peak in new cases was achieved / will be achieved. Bottom-right: Time at which 90 % of K was achieved / will be achieved. Blue dotted line indicates current date. At the end, predicted K for whole EU+EFTA+UK.



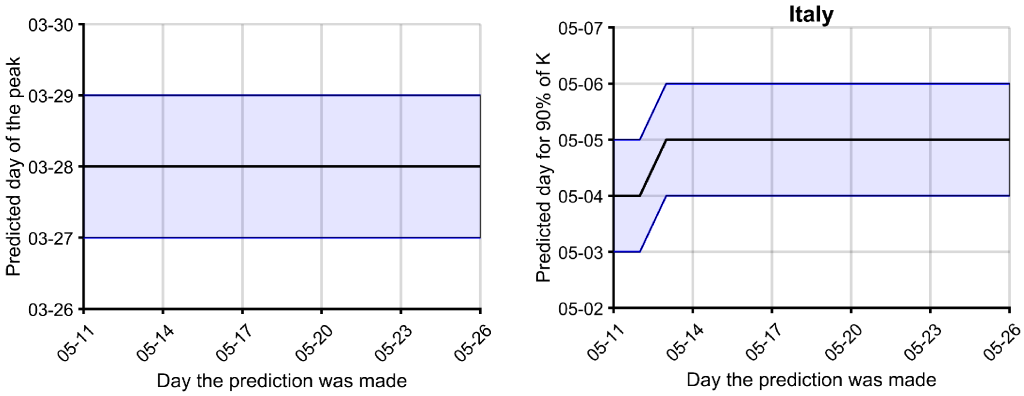
# 2020-05-26


Predicted day of the peak
03-30
03-29
03-28
03-27
03-26
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Spain
Predicted day for 90% of K
04-29
04-28
04-27
04-26
04-25
04-24
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made

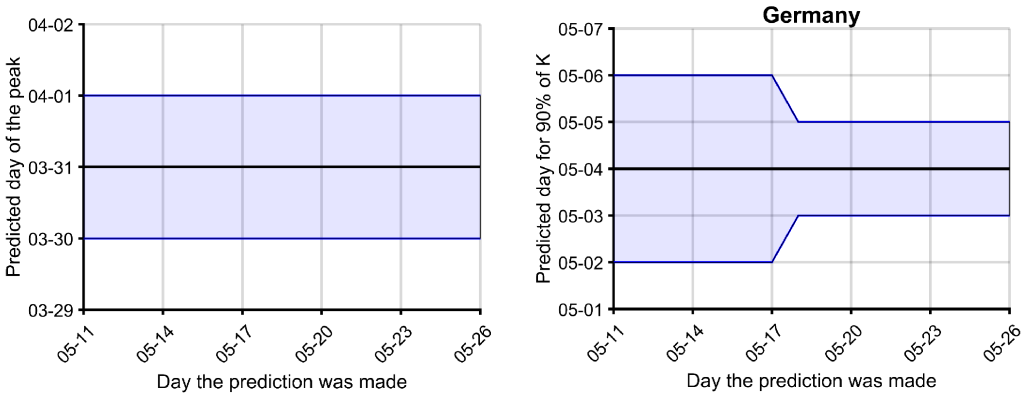

×10^5
Predicted K
3.5
3
2.5
2
1.5
1
0.5
0
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Predicted day of the peak
03-30
03-29
03-28
03-27
03-26
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Italy
Predicted day for 90% of K
05-07
05-06
05-05
05-04
05-03
05-02
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made

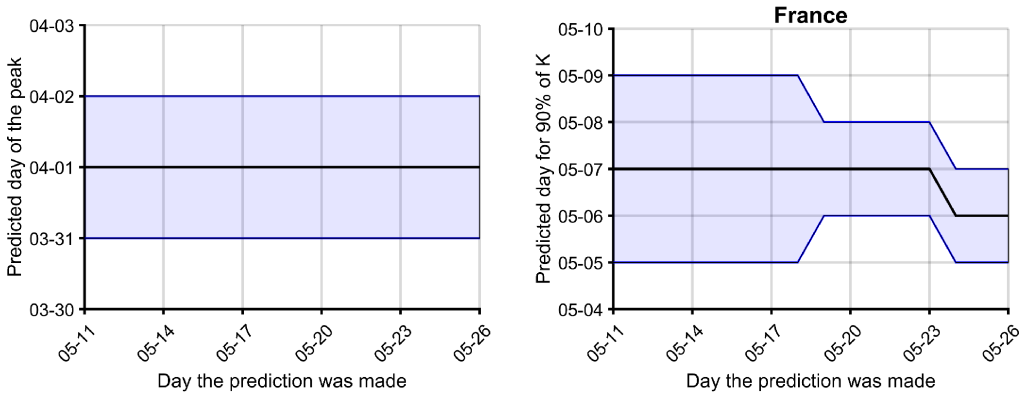

×10^5
Predicted K
3.5
3
2.5
2
1.5
1
0.5
0
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Predicted day of the peak
04-02
04-01
03-31
03-30
03-29
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Germany
Predicted day for 90% of K
05-07
05-06
05-05
05-04
05-03
05-02
05-01
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made

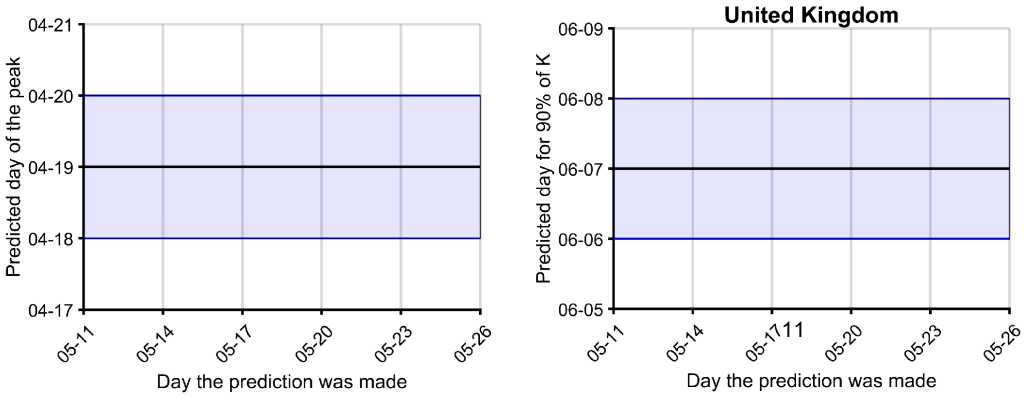

×10^5
Predicted K
2.5
2
1.5
1
0.5
0
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Predicted day of the peak
04-03
04-02
04-01
03-31
03-30
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


France
Predicted day for 90% of K
05-10
05-09
05-08
05-07
05-06
05-05
05-04
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


×10^5
Predicted K
2
1.5
1
0.5
0
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


Predicted day of the peak
04-21
04-20
04-19
04-18
04-17
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


United Kingdom
Predicted day for 90% of K
06-09
06-08
06-07
06-06
06-05
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made


×10^5
Predicted K
4
3
2
1
0
05-11
05-14
05-17
05-20
05-23
05-26
Day the prediction was made

# Situation, trends and long-term predictions in Italian regions[1]

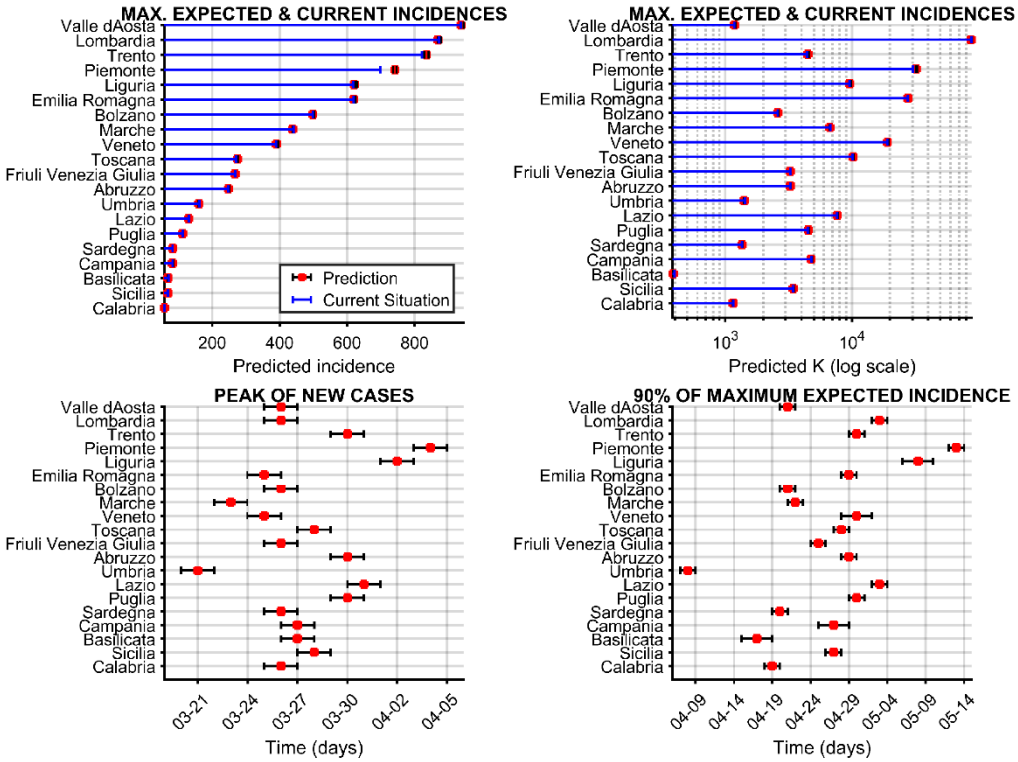
## Situation and trends

| | Reported data | | | | | | | | Indexes | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | Cumulative cases | Attack rate /$10^5$ inh. | Cumulative deaths | Mortality /$10^5$ inh. | Active cases (last 14 days) | 14-day attack rate /$10^5$ inh. | Estimated active cases (last 14 days) | Estimated 14-day attack rate /$10^5$ inh. | $\rho_7$ [1] | $EPG_{REP}$ [2] | $EPG_{EST}$ [3] |
| Lombardia | 87.801 | 874,4 | 15.954 | 158,9 | 4.503 | 44,8 | 83.380 | 828,7 | 0,89 | 40 | 739 |
| Piemonte | 30.387 | 697,5 | 3.828 | 87,9 | 1.329 | 30,5 | 16.920 | 388,4 | 0,73 | 22 | 284 |
| Emilia Romagna | 27.627 | 619,5 | 4.083 | 91,6 | 648 | 14,5 | 9.506 | 213,2 | 0,80 | 12 | 171 |
| Veneto | 19.113 | 389,6 | 1.895 | 38,6 | 300 | 6,1 | 3.011 | 61,4 | 0,57 | 4 | 35 |
| Toscana | 10.082 | 270,3 | 1.027 | 27,5 | 253 | 6,8 | 2.604 | 69,8 | 0,72 | 5 | 50 |
| Liguria | 9.589 | 618,4 | 1.438 | 92,7 | 659 | 42,5 | 10.012 | 645,5 | 0,87 | 37 | 562 |
| Lazio | 7.672 | 130,5 | 701 | 11,9 | 422 | 7,2 | 3.947 | 67,1 | 0,60 | 4 | 40 |
| Marche | 6.718 | 440,4 | 996 | 65,3 | 130 | 8,5 | 1.966 | 128,9 | 0,76 | 7 | 98 |
| Campania | 4.773 | 82,3 | 406 | 7,0 | 143 | 2,5 | 1.237 | 21,3 | 0,74 | 2 | 16 |
| Puglia | 4.479 | 111,2 | 495 | 12,3 | 131 | 3,3 | 1.478 | 36,7 | 1,34 | 4 | 49 |
| Trento | 4.422 | 412,4 | 462 | 43,1 | 110 | 10,3 | 1.176 | 218,7 | 0,97 | 10 | 212 |
| Sicilia | 3.435 | 68,7 | 272 | 5,4 | 81 | 1,6 | 640 | 12,8 | 0,53 | 1 | 7 |
| Friuli Venezia Giulia | 3.255 | 267,9 | 331 | 27,2 | 99 | 8,1 | 1.026 | 84,4 | 0,87 | 7 | 74 |
| Abruzzo | 3.235 | 246,6 | 400 | 30,5 | 108 | 8,2 | 1.351 | 103,0 | 0,45 | 4 | 46 |
| Bolzano | 2.593 | 2.413,5 | 291 | 270,9 | 18 | 16,8 | 202 | 38,9 | 0,74 | 12 | 29 |
| Umbria | 1.431 | 162,2 | 75 | 8,5 | 12 | 1,4 | NA | NA | 0,70 | 1 | NA |
| Sardegna | 1.355 | 82,6 | 130 | 7,9 | 10 | 0,6 | NA | NA | NA | NA | NA |
| Valle dAosta | 1.181 | 940,2 | 143 | 113,8 | 18 | 14,3 | 214 | 170,0 | 1,00 | 14 | 170 |
| Calabria | 1.158 | 59,5 | 96 | 4,9 | 18 | 0,9 | NA | NA | 0,26 | 0 | NA |
| Molise | 434 | 142,0 | 22 | 7,2 | 33 | 10,8 | NA | NA | 0,57 | 6 | NA |
| Basilicata | 399 | 70,9 | 27 | 4,8 | 10 | 1,8 | NA | NA | 1,60 | 3 | NA |
| | Scale | | | | | | | | | | |
| | Worst | Worst | Worst | Worst | Worst | Worst | Worst | Worst | 2,0 | 100 | 1000 |
| | Best | Best | Best | Best | Best | Best | Best | Best | 0,0 | 0 | 0 |

[1] $\rho_7$ is the average of 7 consecutive ρ, but can still fluctuate. [2,3] EPG stands for Effective Growth Potential. $EPG_{REP}$ is obtained by multiplying attack rate of last 14 days per $10^5$ inhabitants (i.e. density of cases) by $\rho_7$ (a value related with effective reproduction number and that, therefore, determines the dynamics for subsequent days). $EPG_{EST}$ is obtained by multiplying estimated real attack rate of last 14 days per $10^5$ inhabitants by $\rho_7$.

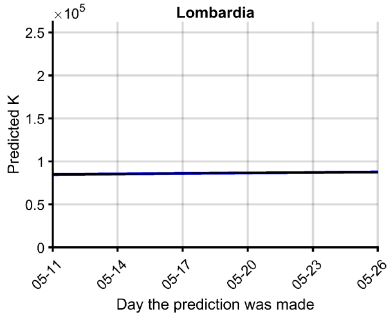
**Disclaimer:** estimated active cases and estimated 14-day attack rate are assessed by assuming a lethality of 1 % (see report from 20 to 24 April, #37-41). This value can change in countries where suspicious deaths are reported as well (real values would be lower) and in countries where incidence among elderly people was minor (real values would be higher).

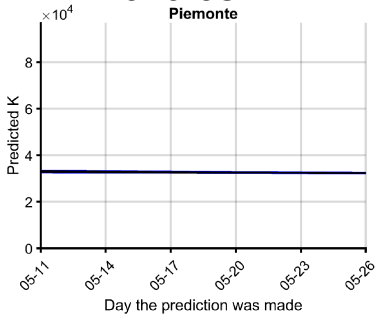
## Long-term predictions

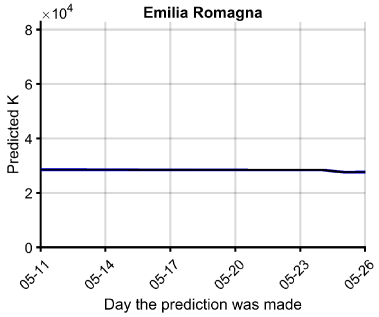


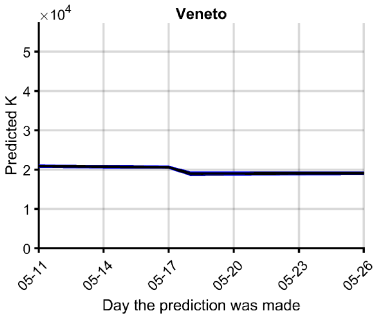

[1] **Spain:** Historical series have not been updated. Therefore, regional analysis is not shown

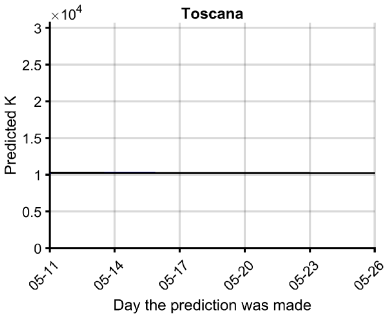
# 2020-05-27

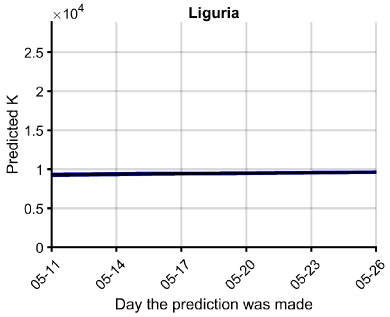

Lombardia
×10^5
Predicted K
Day the prediction was made

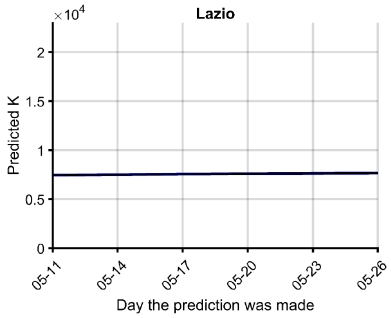

Piemonte
×10^4
Predicted K
Day the prediction was made

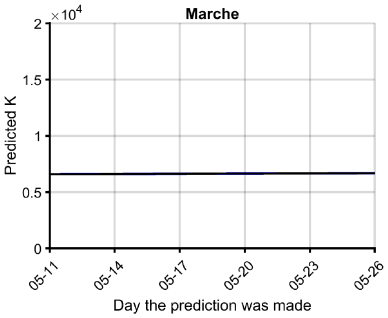

Emilia Romagna
×10^4
Predicted K
Day the prediction was made

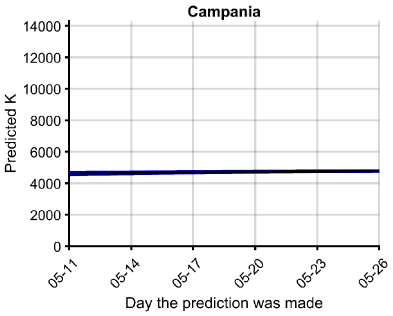

Veneto
×10^4
Predicted K
Day the prediction was made

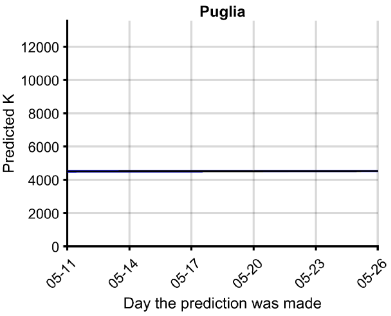

Toscana
×10^4
Predicted K
Day the prediction was made

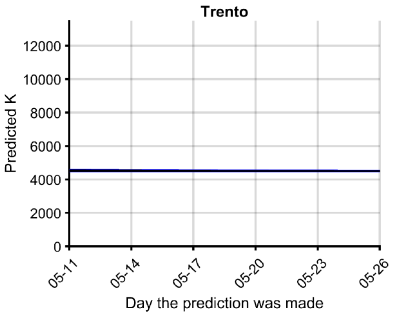

Liguria
×10^4
Predicted K
Day the prediction was made

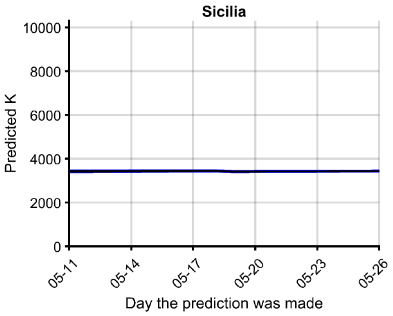

Lazio
×10^4
Predicted K
Day the prediction was made

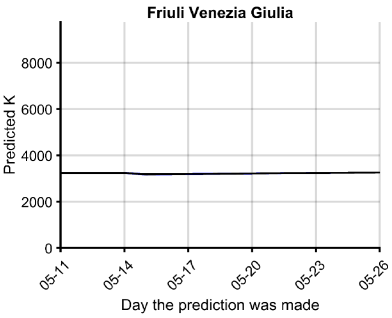

Marche
×10^4
Predicted K
Day the prediction was made

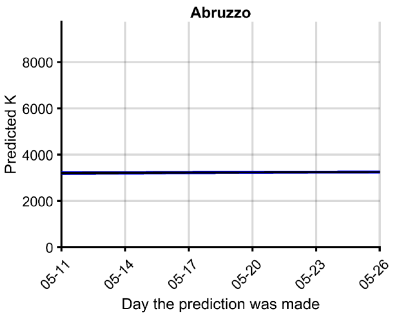

Campania
Predicted K
Day the prediction was made

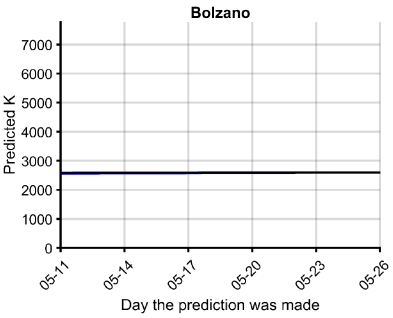

Puglia
Predicted K
Day the prediction was made

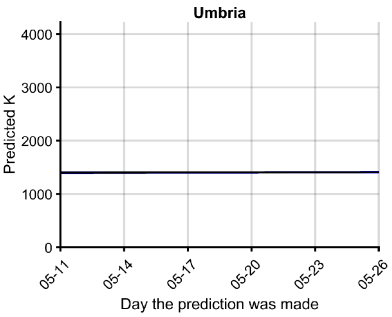

Trento
Predicted K
Day the prediction was made

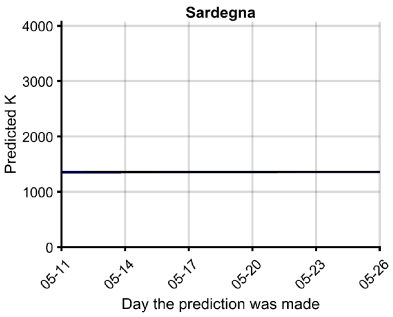

Sicilia
Predicted K
Day the prediction was made

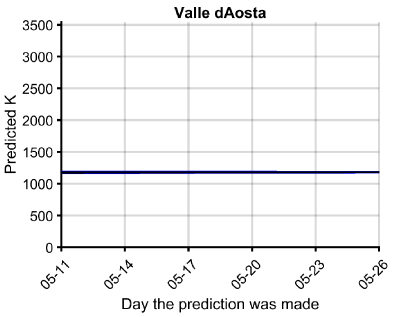

Friuli Venezia Giulia
Predicted K
Day the prediction was made

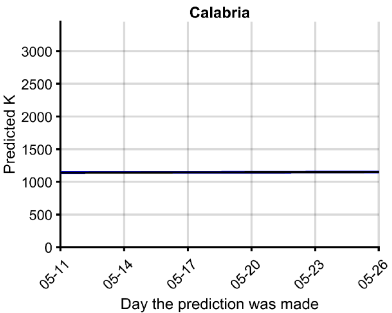

Abruzzo
Predicted K
Day the prediction was made

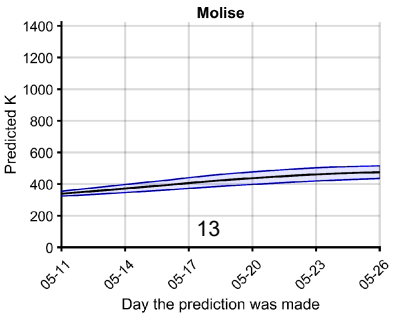

Bolzano
Predicted K
Day the prediction was made

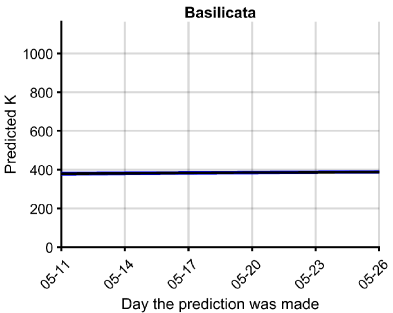

Umbria
Predicted K
Day the prediction was made


Sardegna
Predicted K
Day the prediction was made


Valle dAosta
Predicted K
Day the prediction was made


Calabria
Predicted K
Day the prediction was made

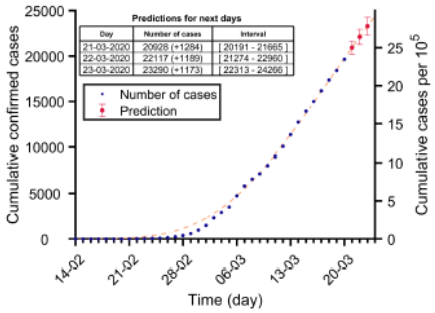

Molise
Predicted K
Day the prediction was made

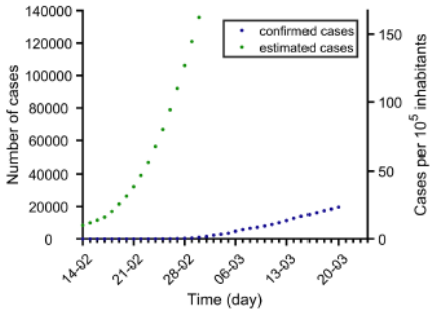

Basilicata
Predicted K
Day the prediction was made

## Legend: Countries' reports details

Iran 20-03-2020. Population: 83.7M. Current cumulated incidence: $23/10^5$

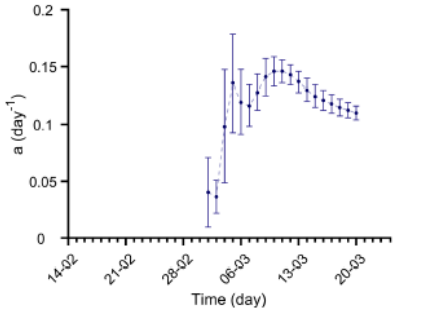
Confirmed cases: data (blue), model fitted (dashed line), predictions (red points and table)

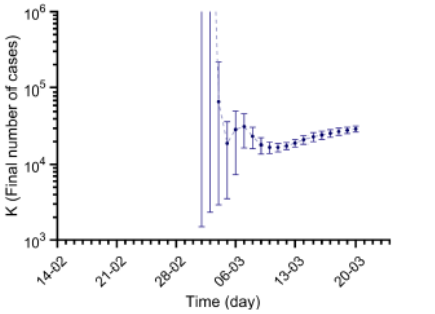



Estimated cases using death rate (see Methods)

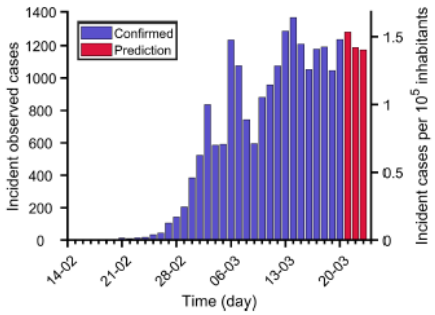
Fitted *a* value using points prior to each date

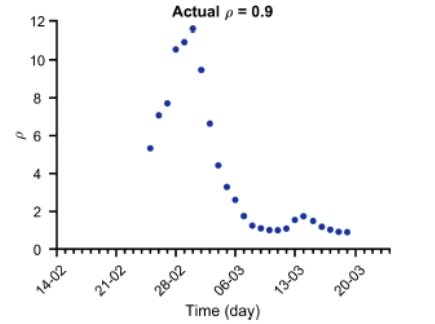



Fitted *K* value using points prior to each date

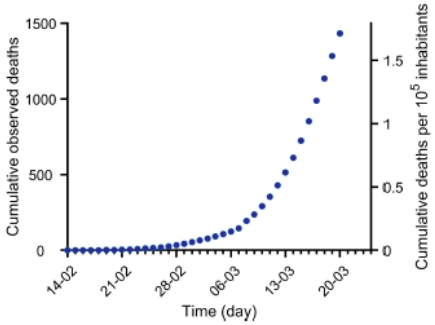
Reported and predicted new cases

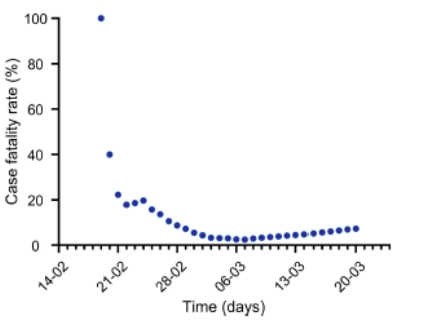



Evolution of $\rho$, a parameter related with Reproduction number (see Methods)

Reported deaths



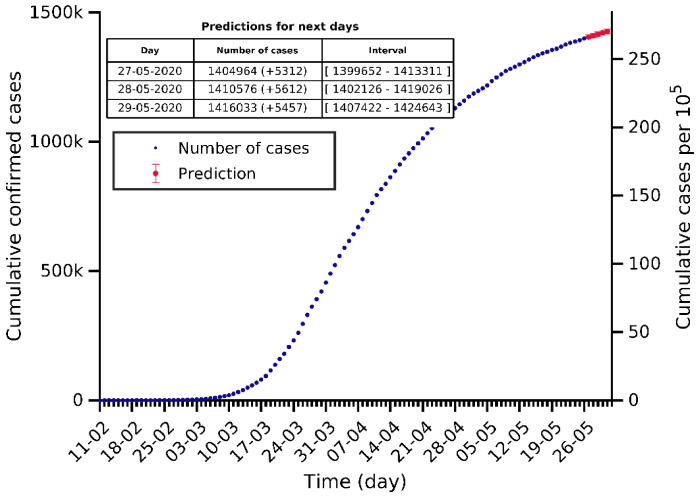



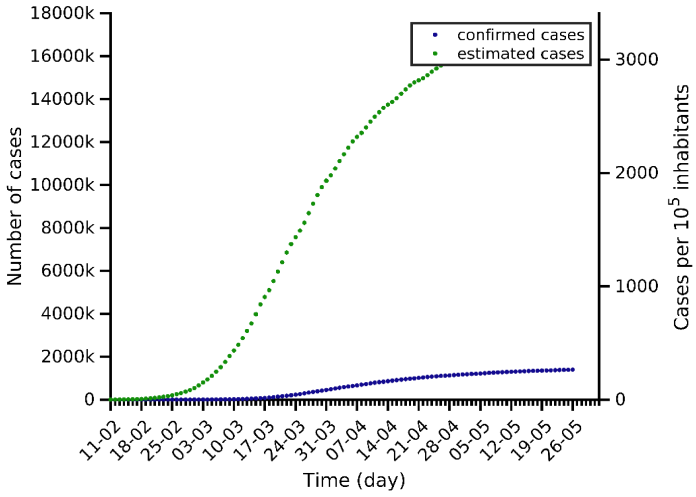

Deaths / cumulated reported cases

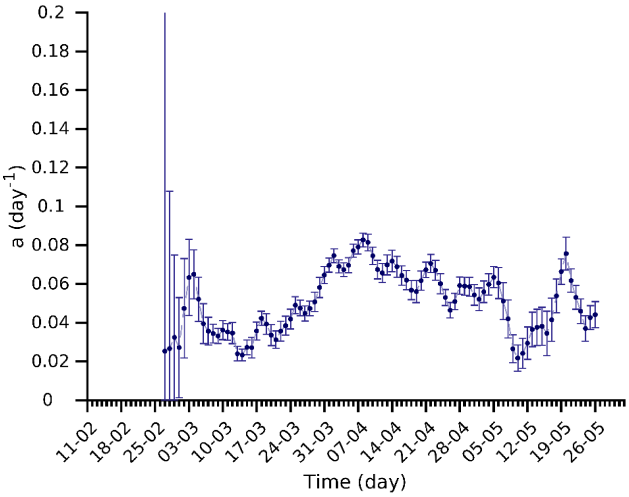
# (1) Analysis and prediction of COVID-19 for EU+EFTA+UK

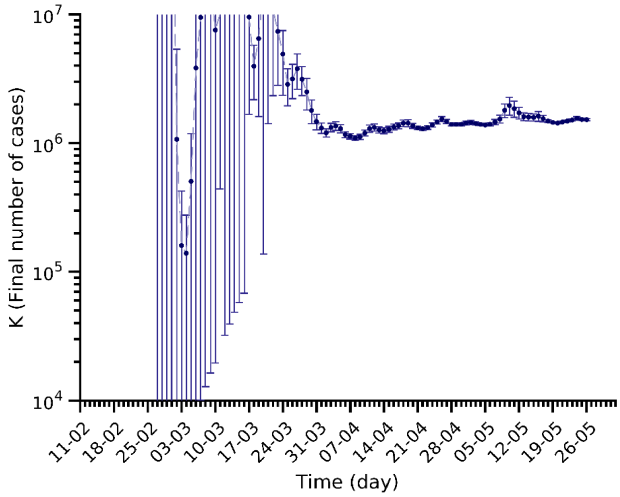
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

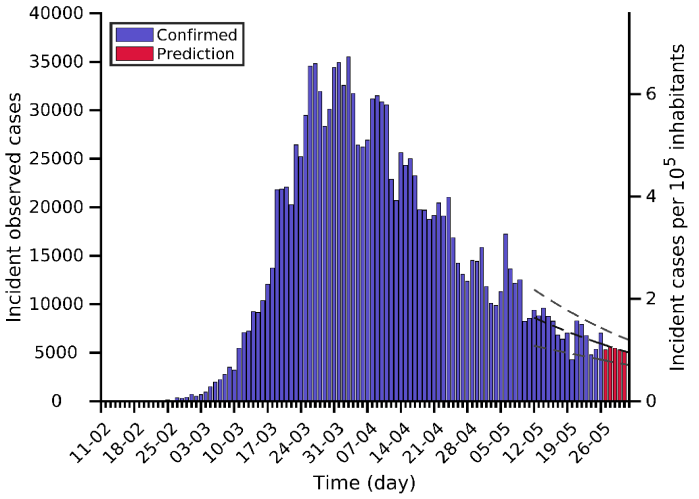
# EU+EFTA+UK 26-05-2020. Population: 527.9M. Current cumulated incidence: 265/1

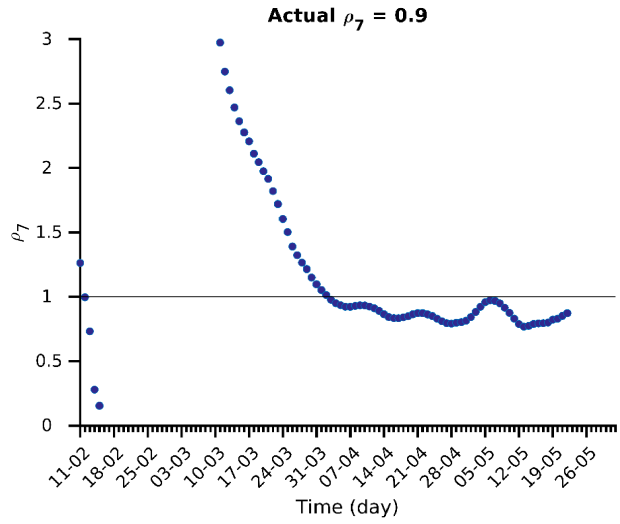


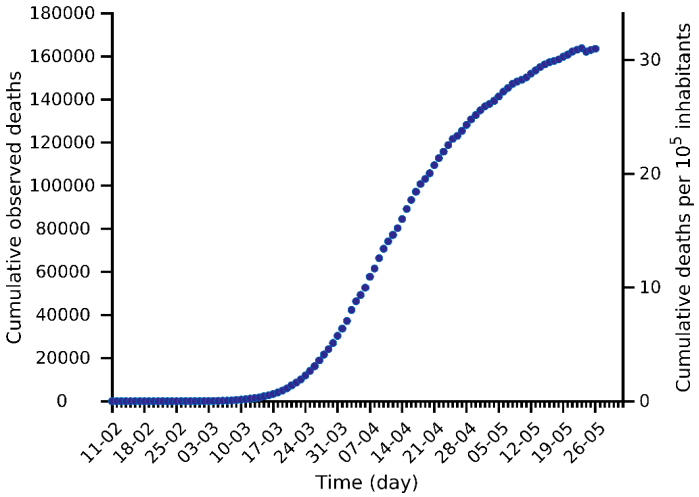



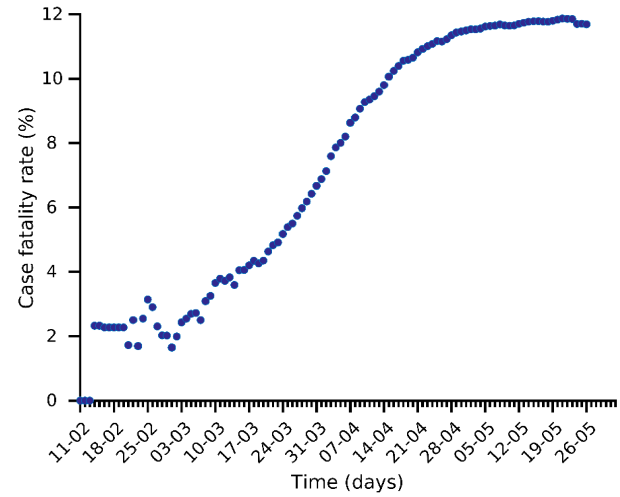



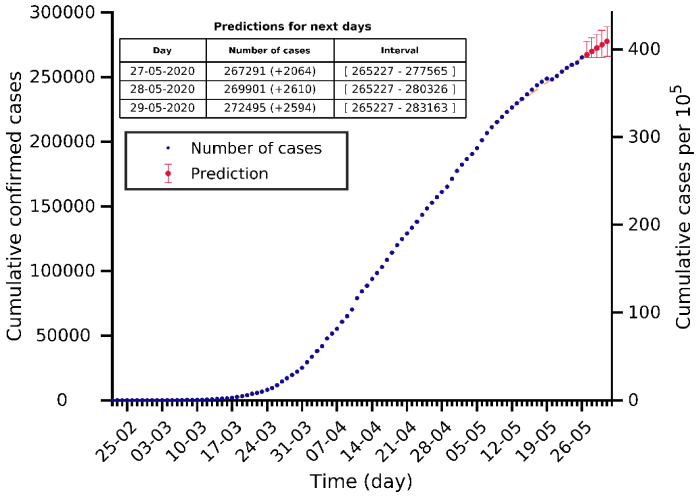



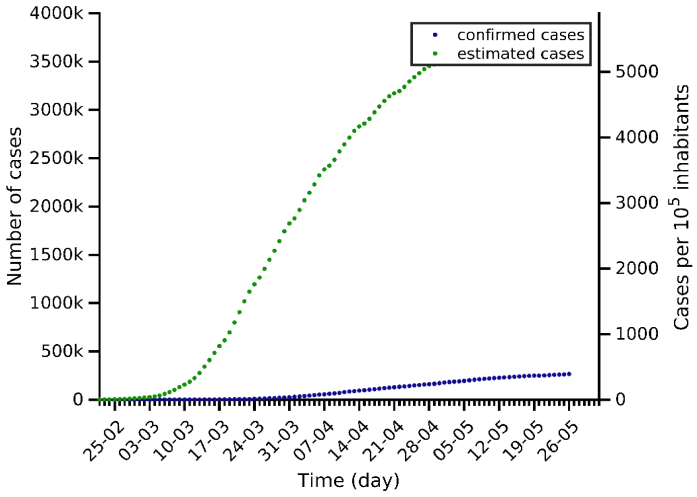



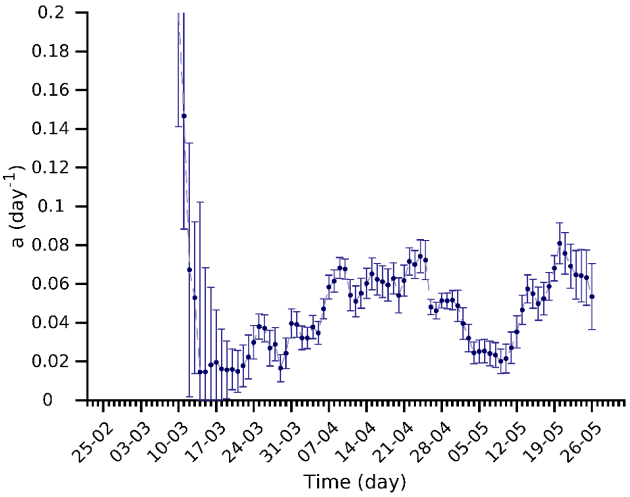



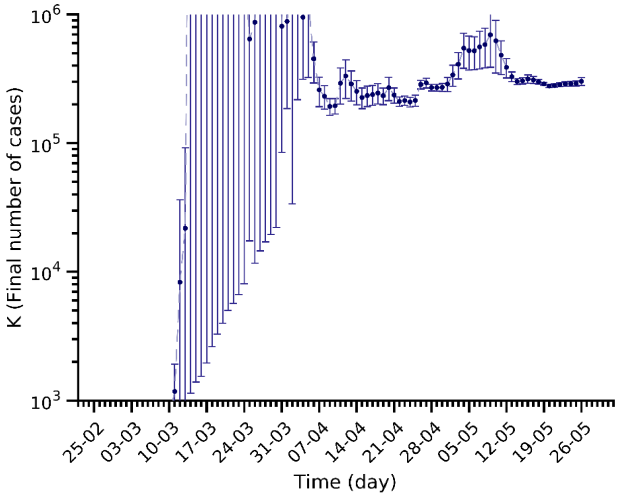



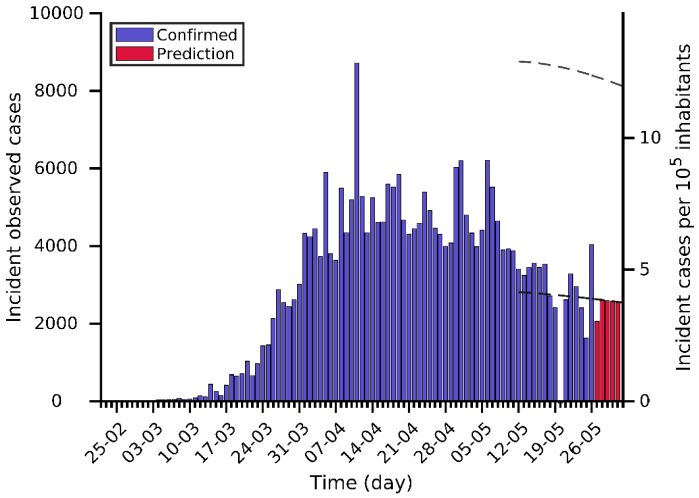
# UK 26-05-2020. Population: 67.9M. Current cumulated incidence: 391/$10^5$

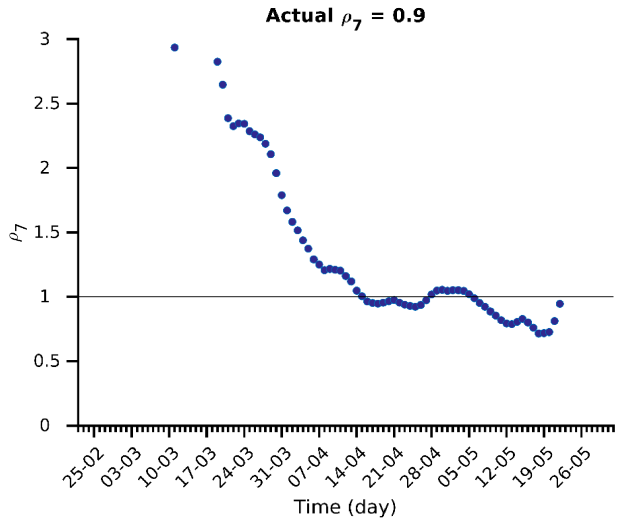


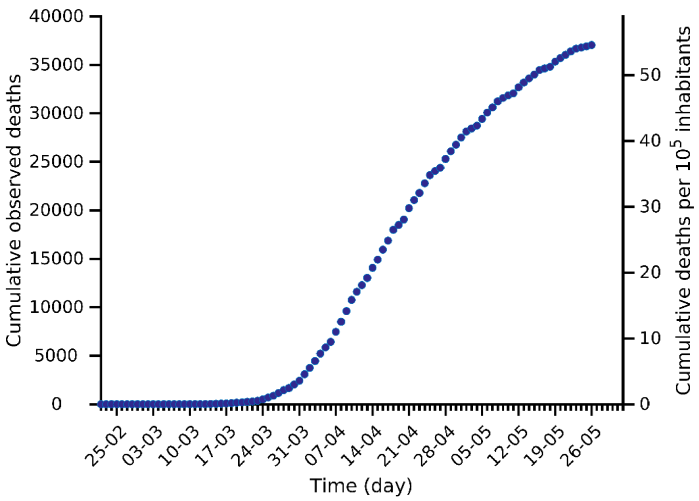



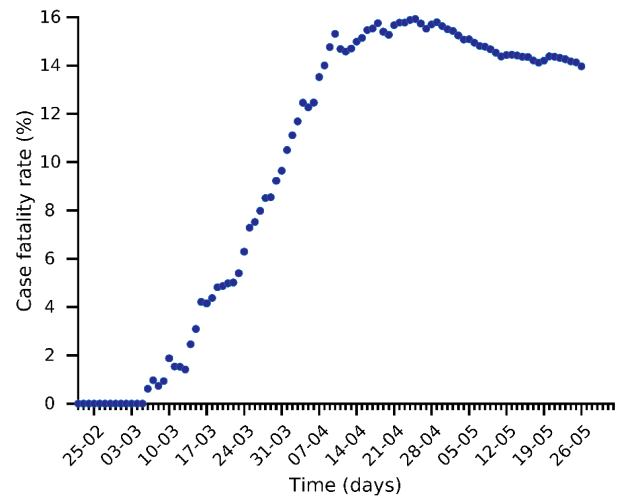



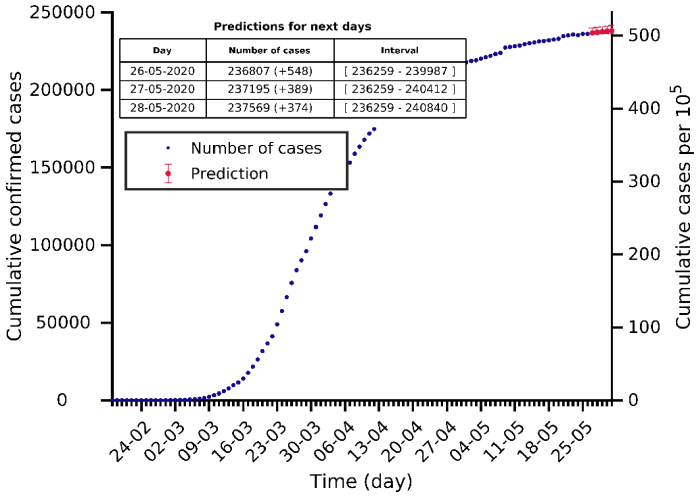



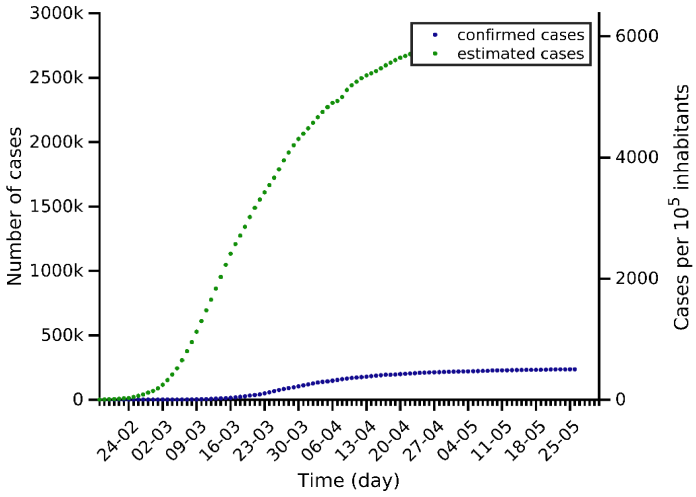



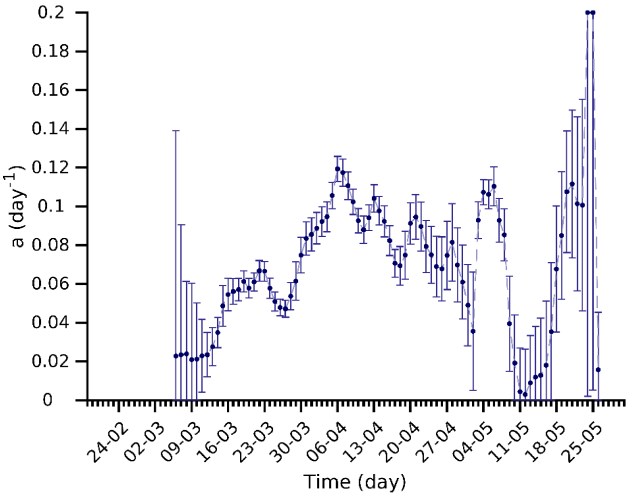



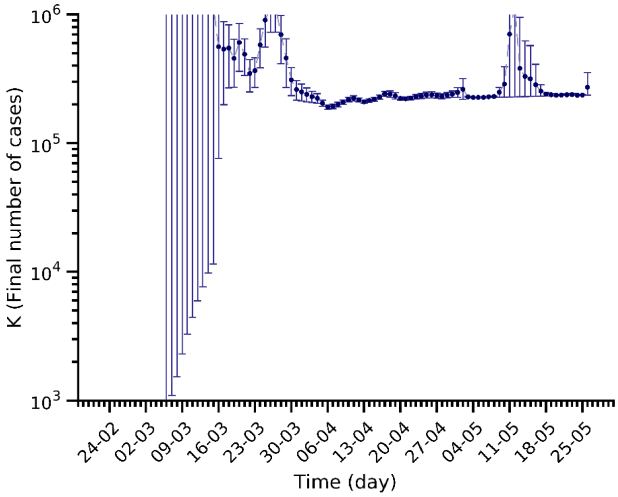



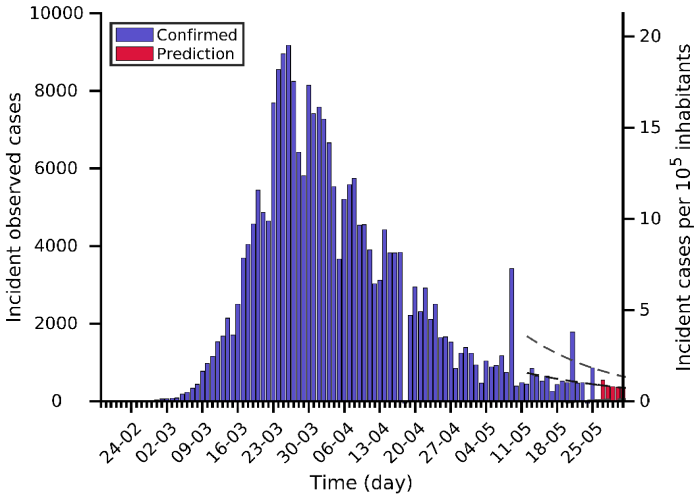
# Spain 25-05-2020. Population: 47.0M. Current cumulated incidence: 502/10⁵

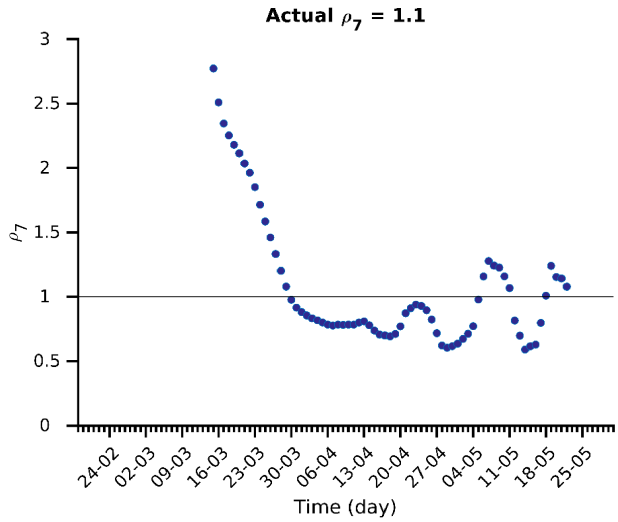


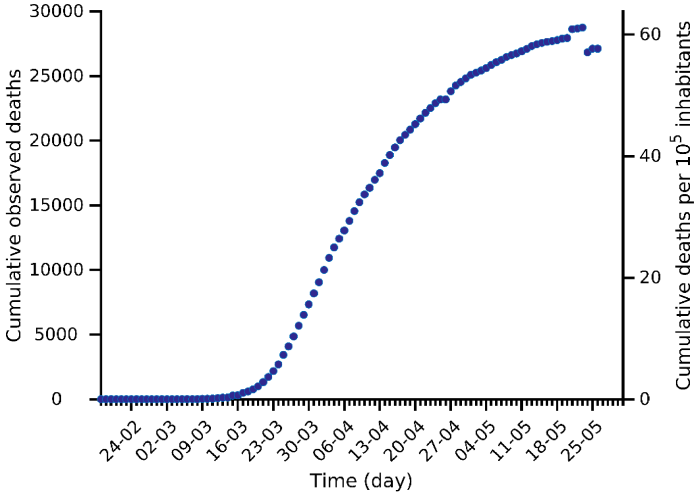



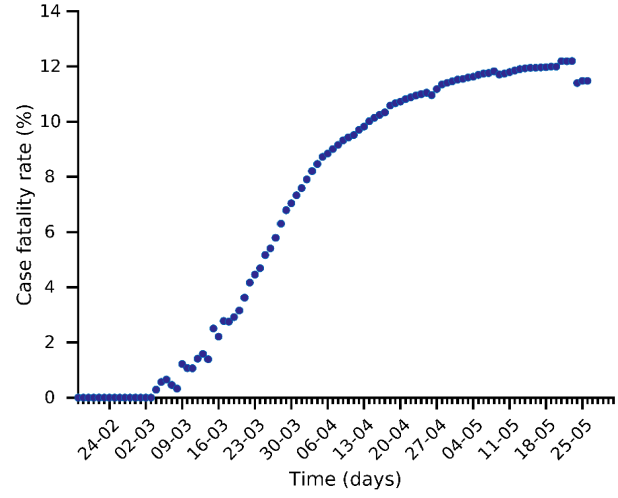



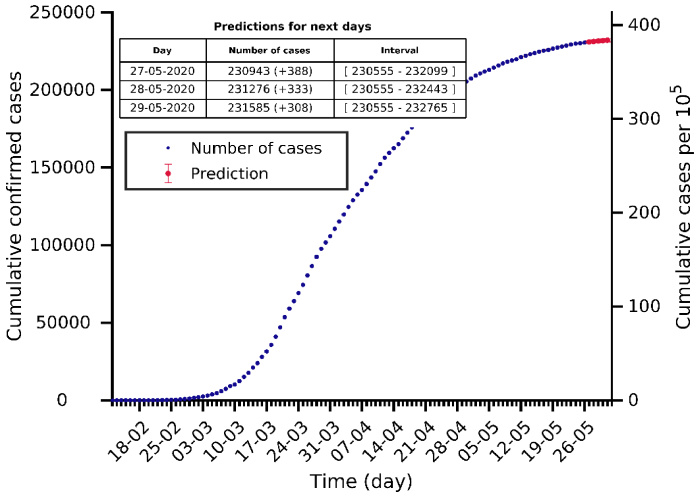



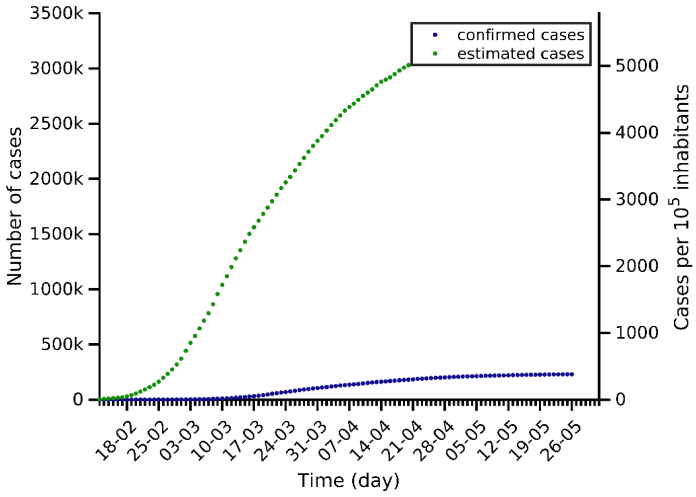



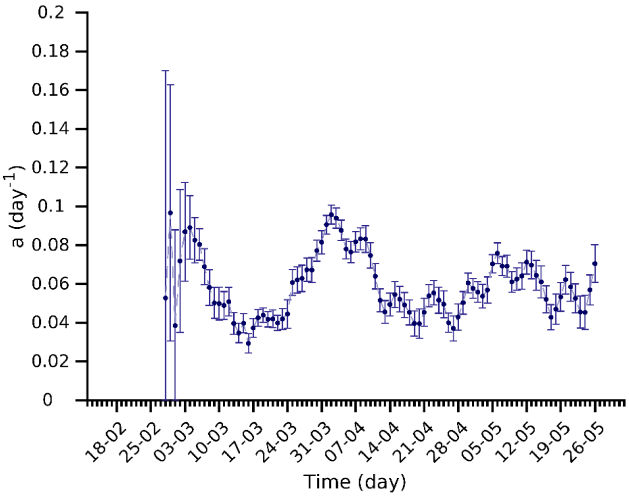



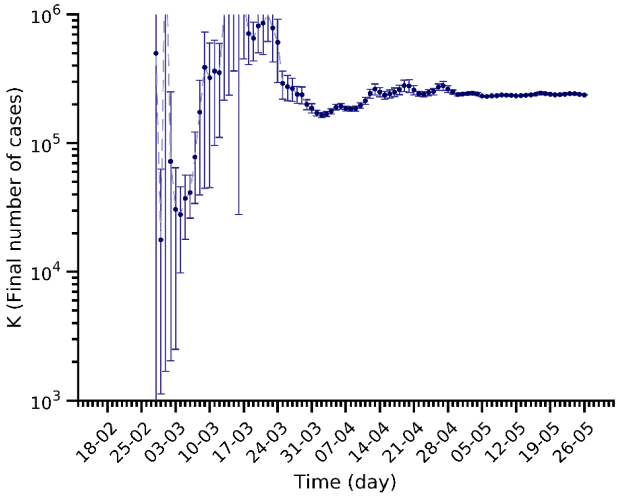



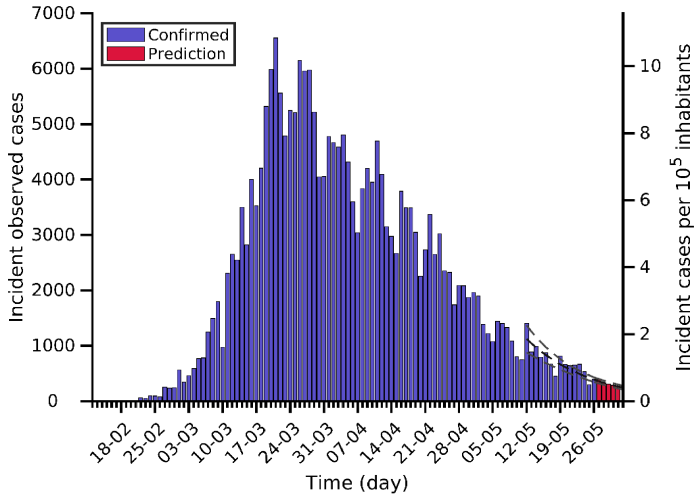
# Italy 26-05-2020. Population: 60.5M. Current cumulated incidence: $381/10^5$

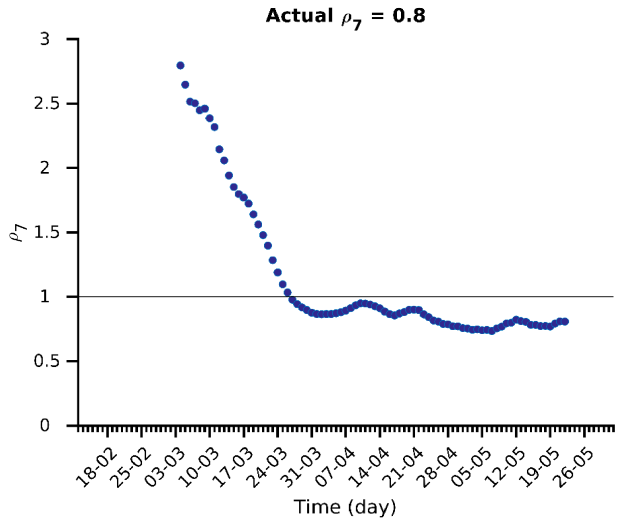


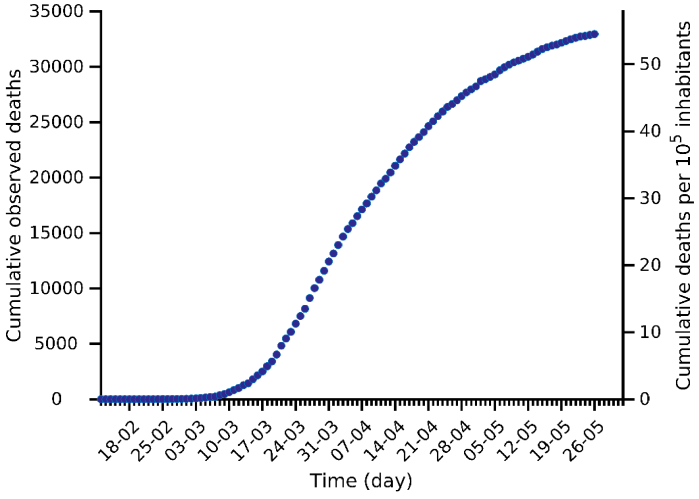



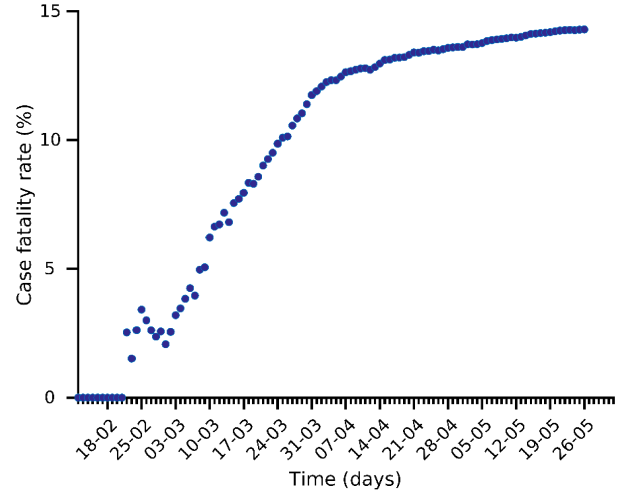



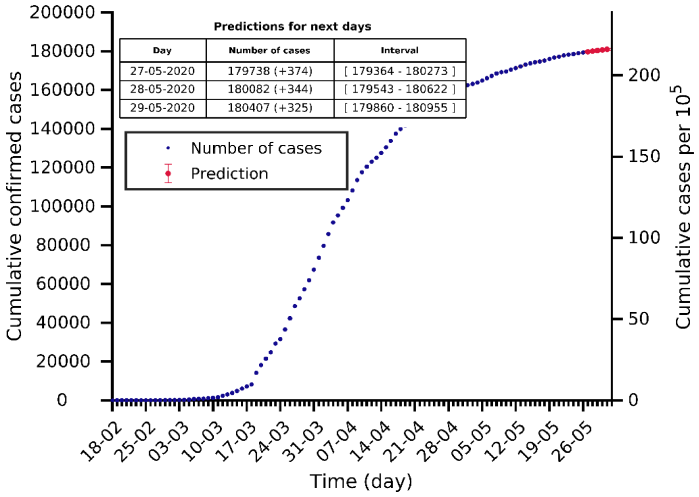



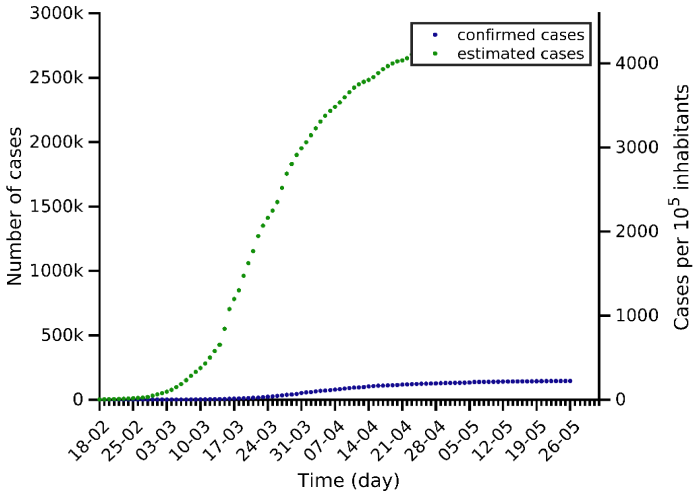



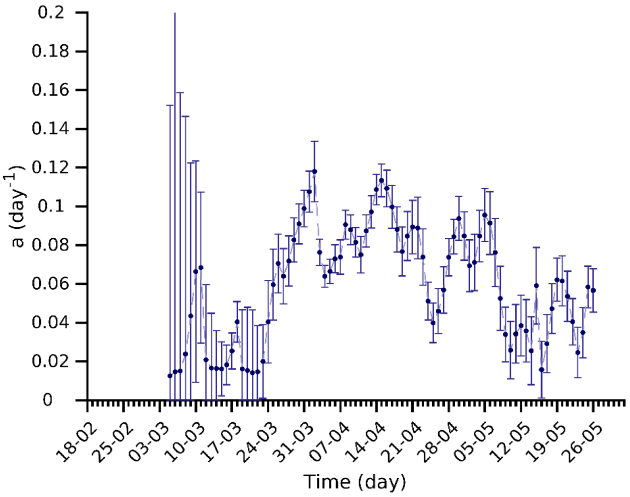



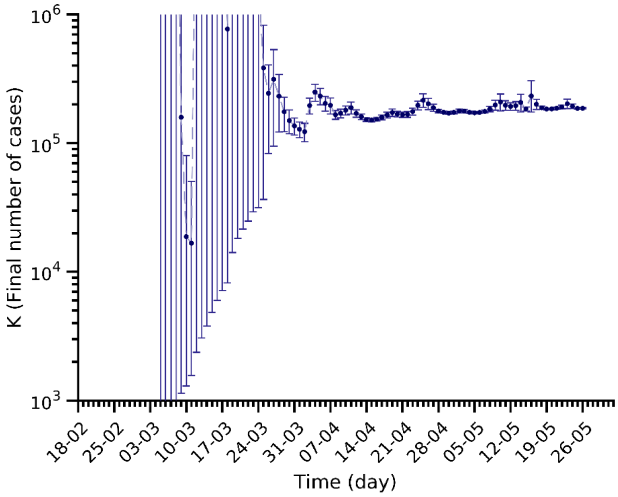



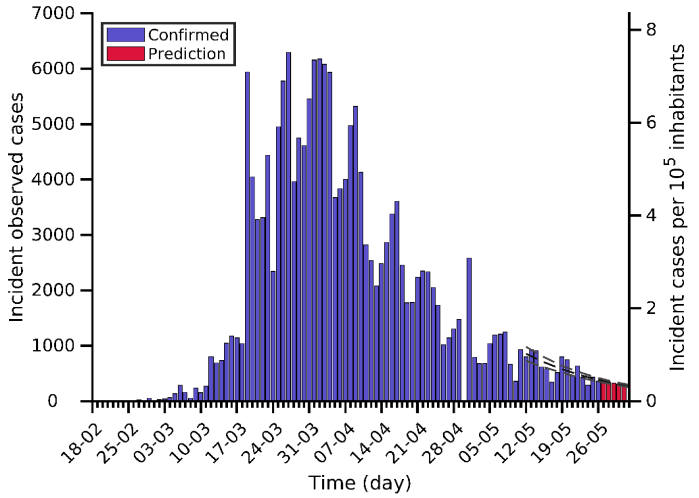
# Germany 26-05-2020. Population: 83.8M. Current cumulated incidence: 214/$10^5$

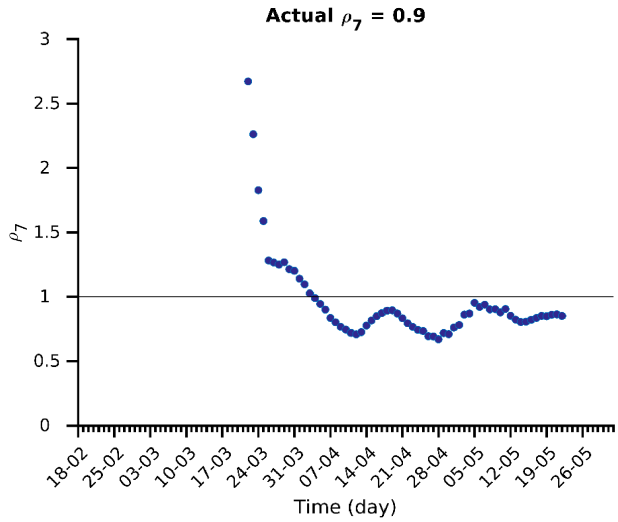


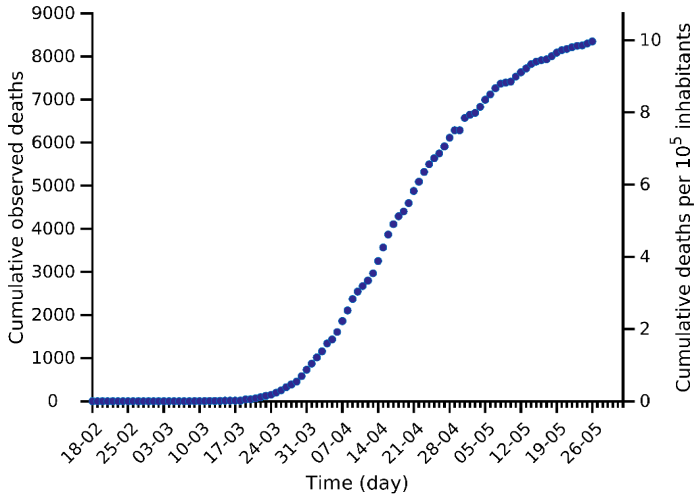



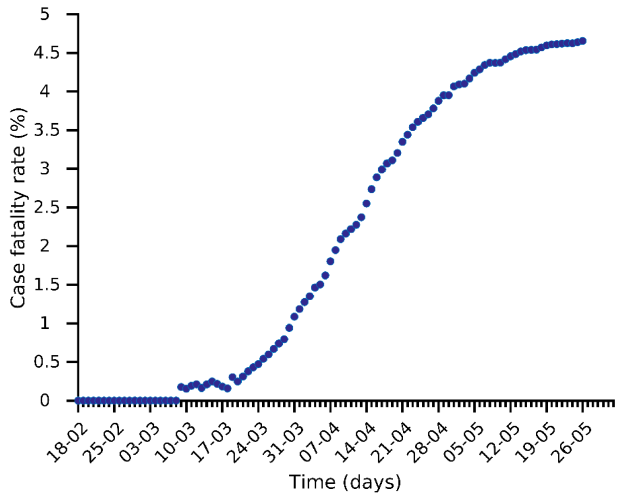



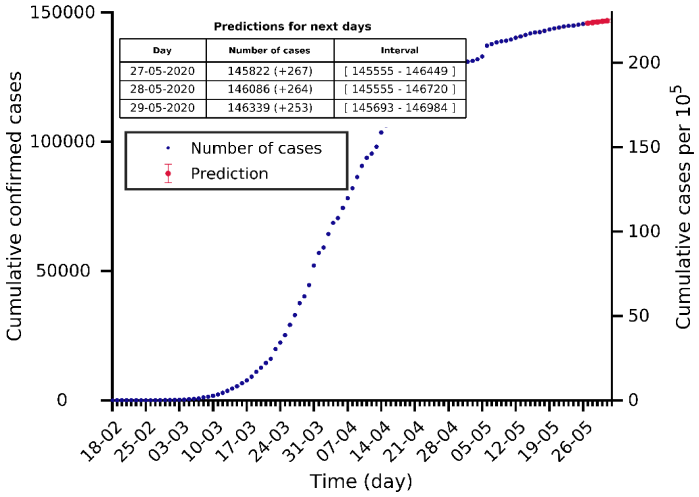



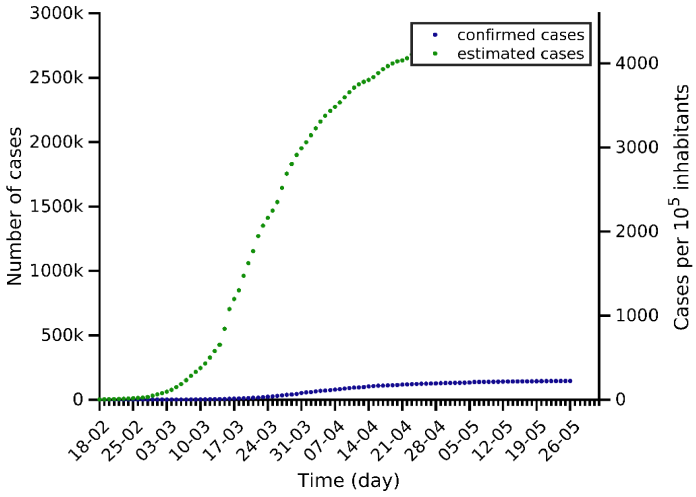



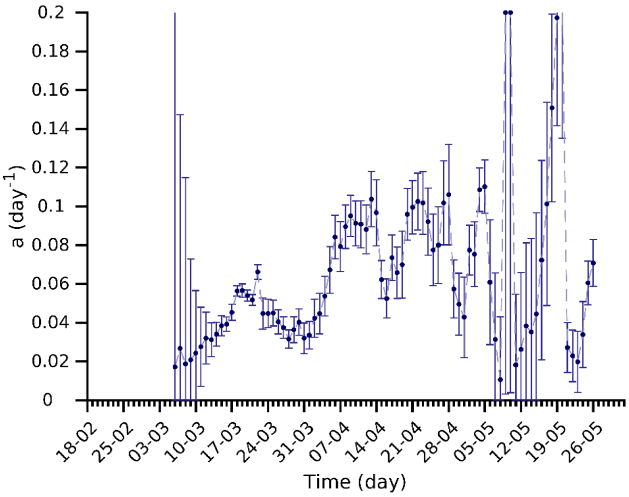



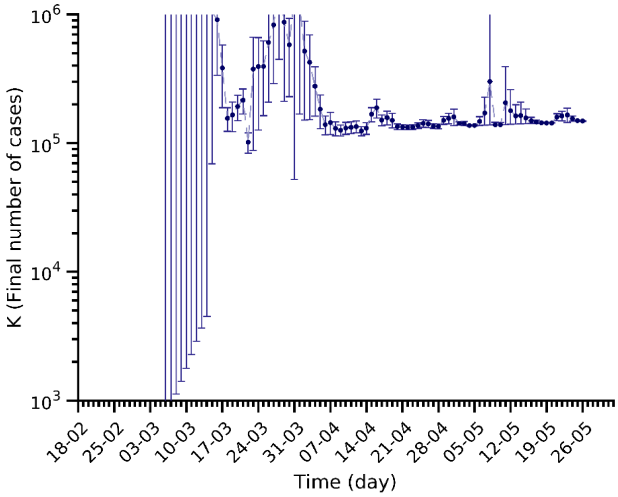



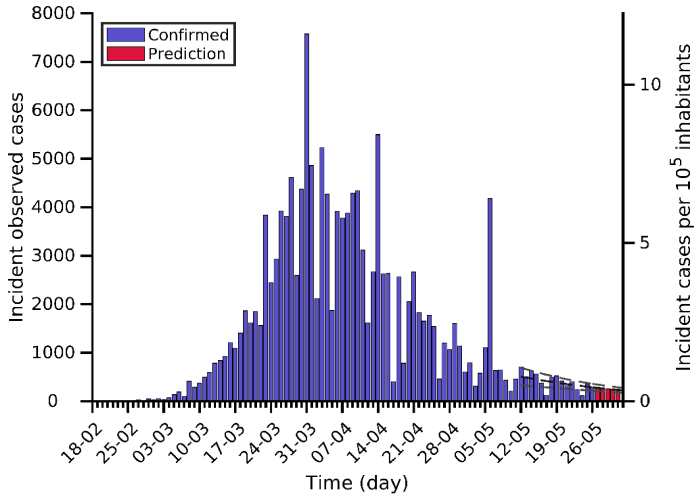
# France 26-05-2020. Population: 65.3M. Current cumulated incidence: 223/$10^5$

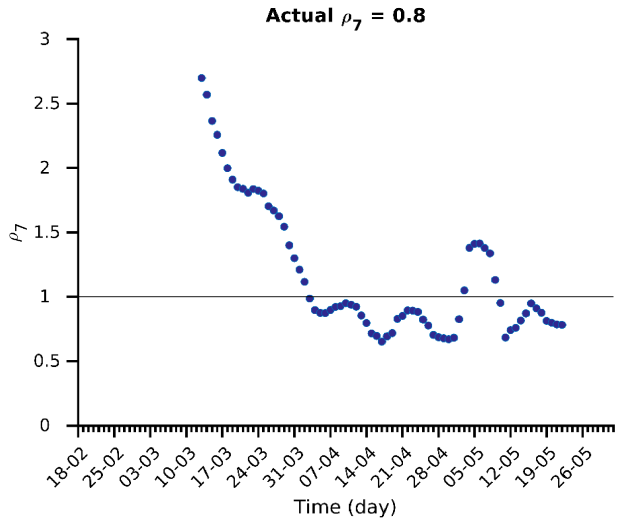


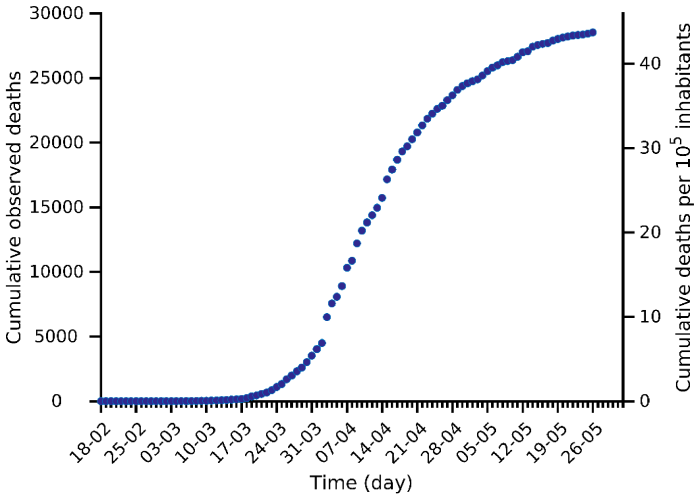



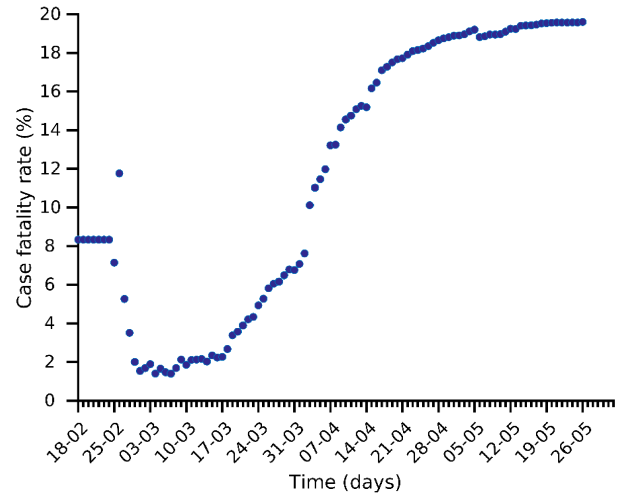



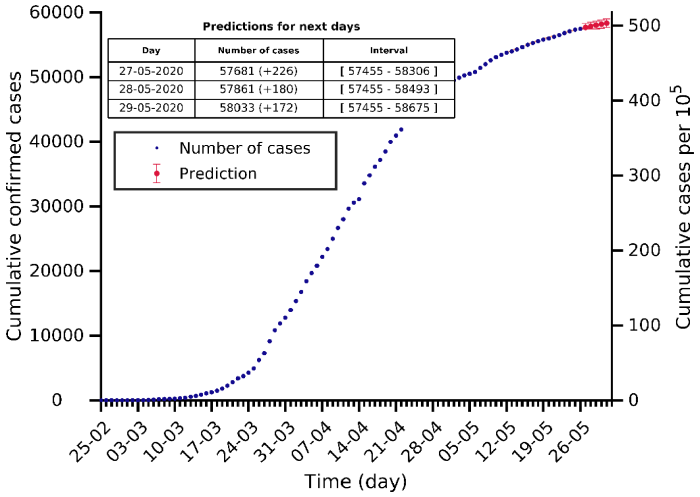



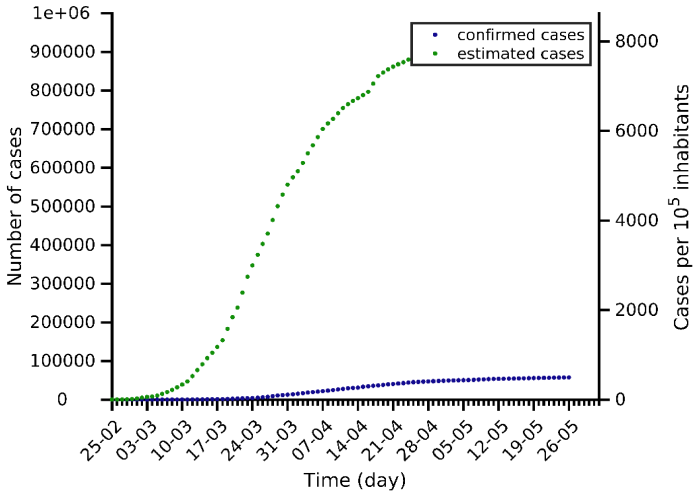



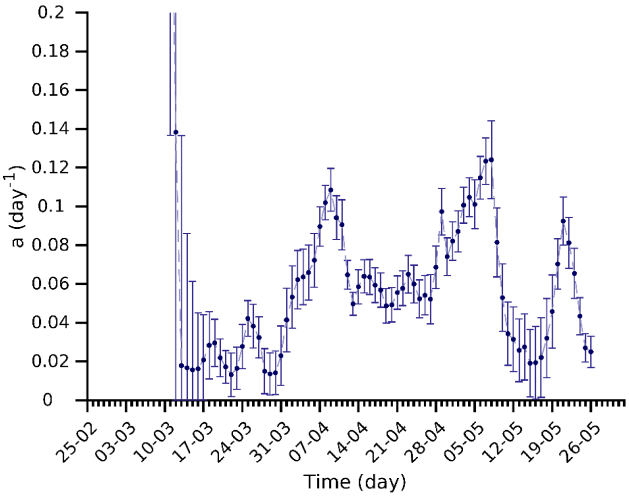



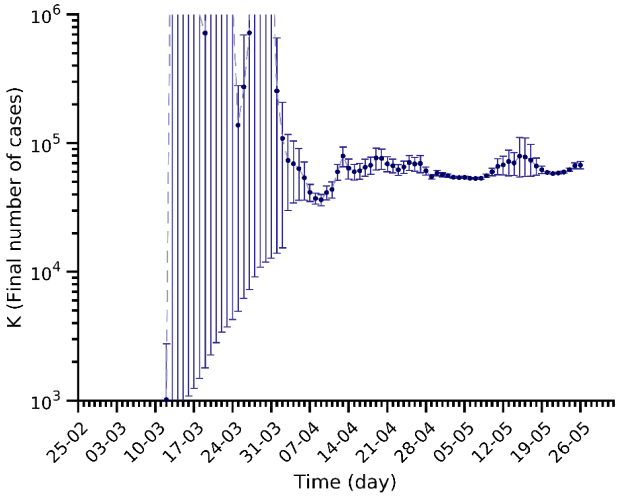



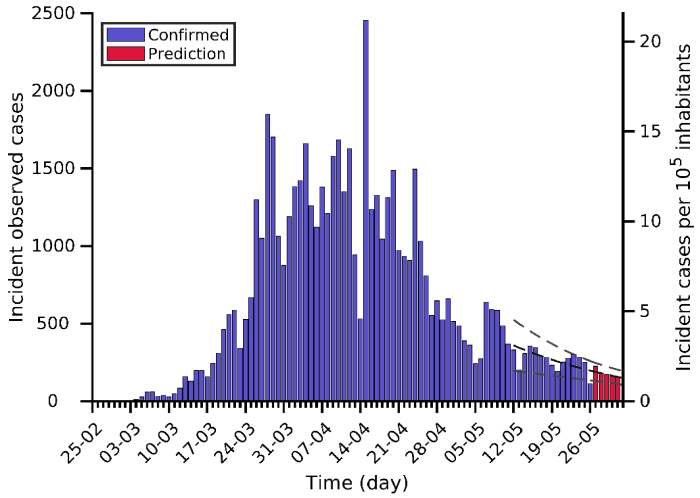
# Belgium 26-05-2020. Population: 11.6M. Current cumulated incidence: 496/$10^5$

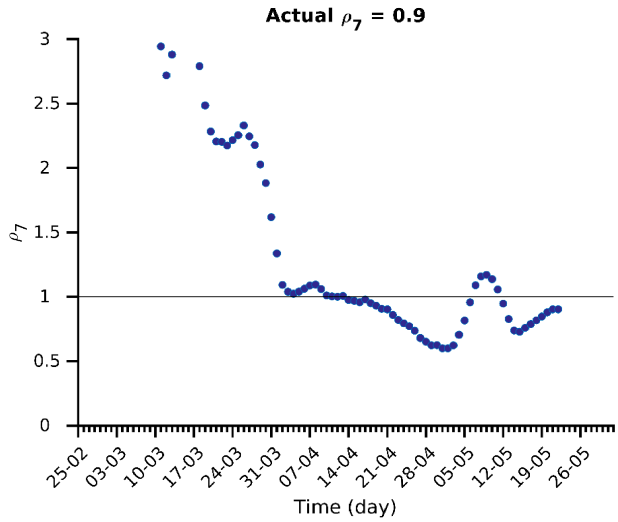


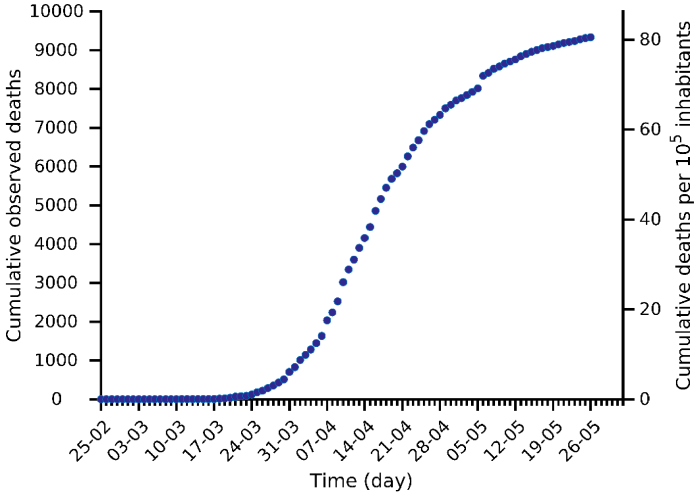



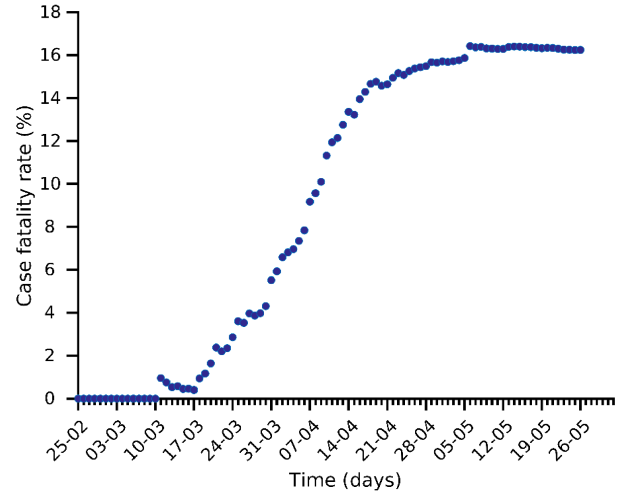



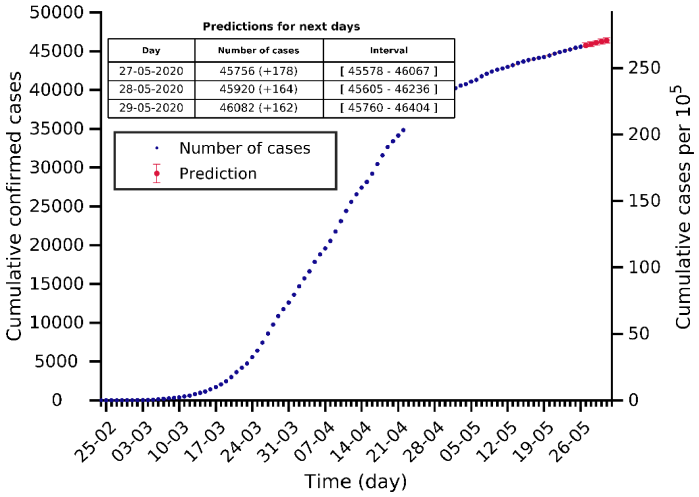



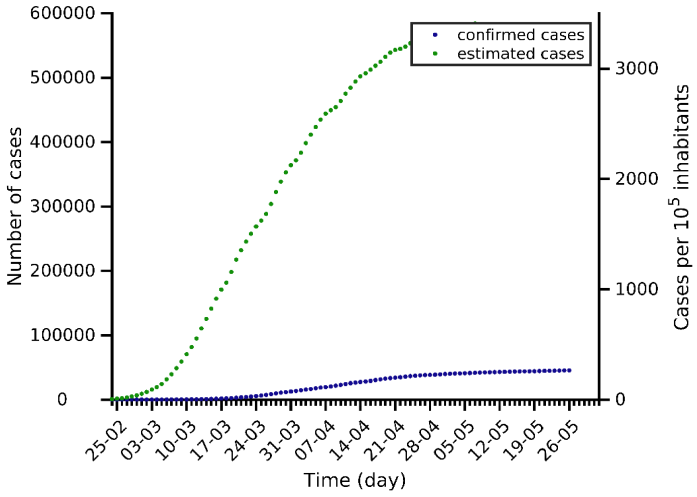



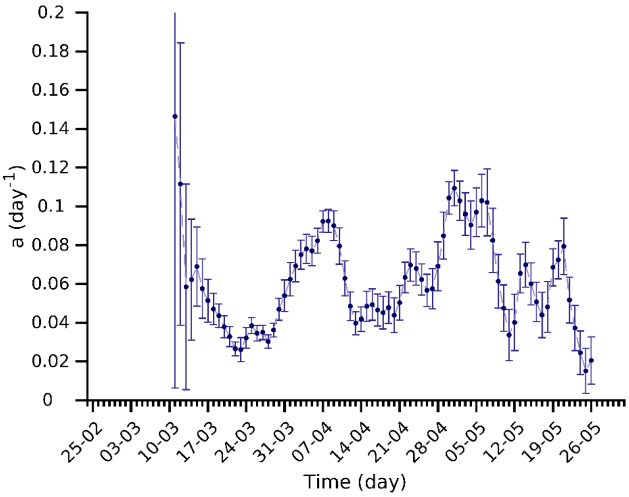



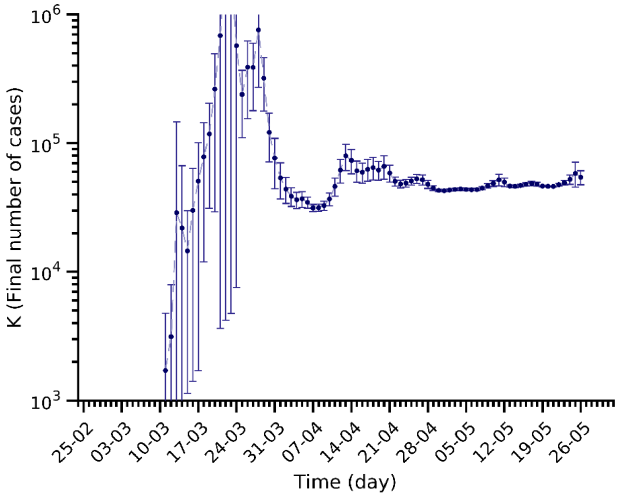



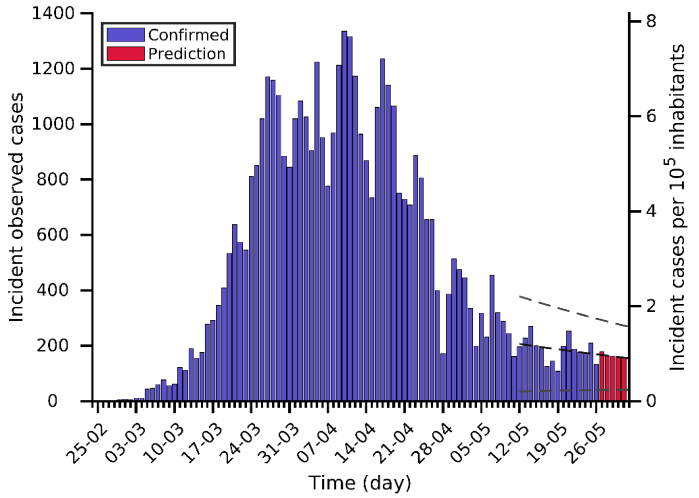
# Netherlands 26-05-2020. Population: 17.1M. Current cumulated incidence: 266/$10^5$

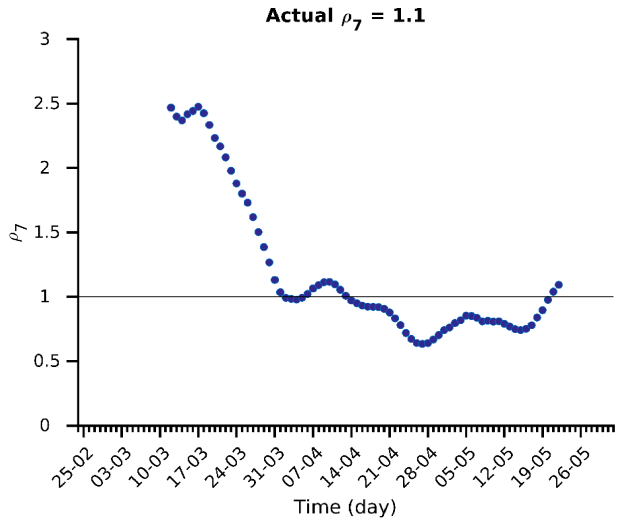


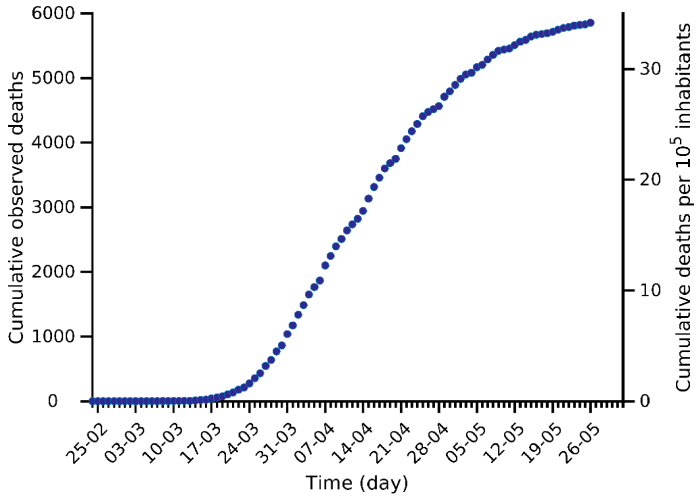



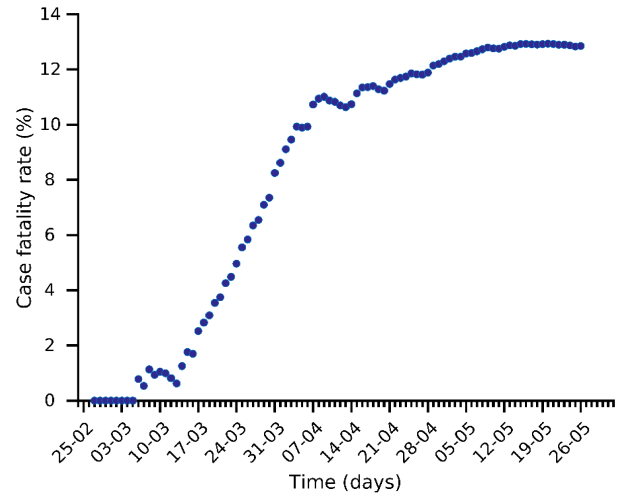



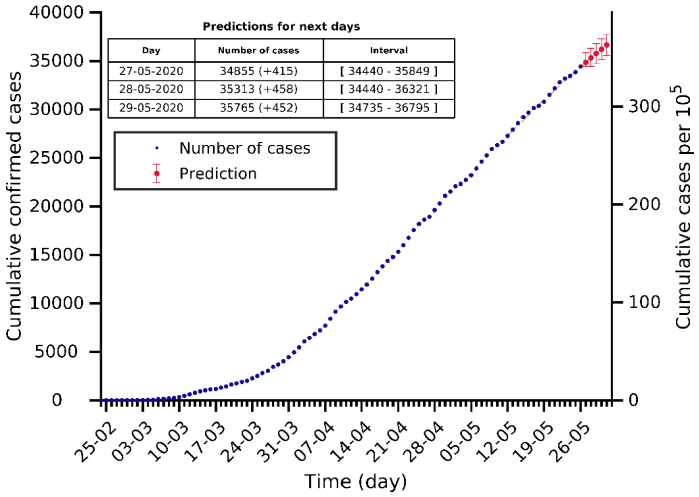



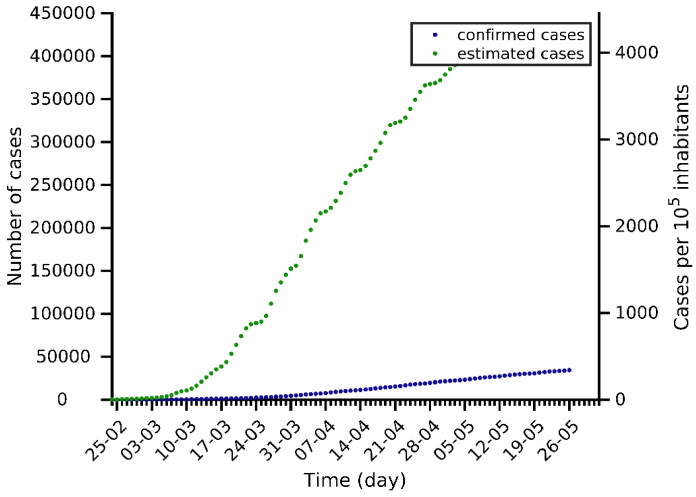



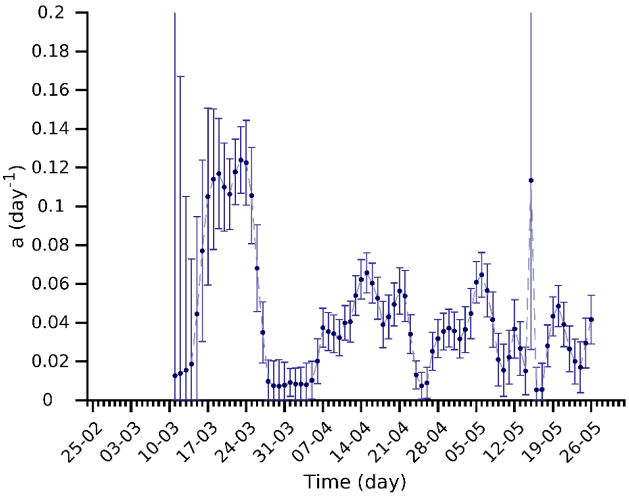



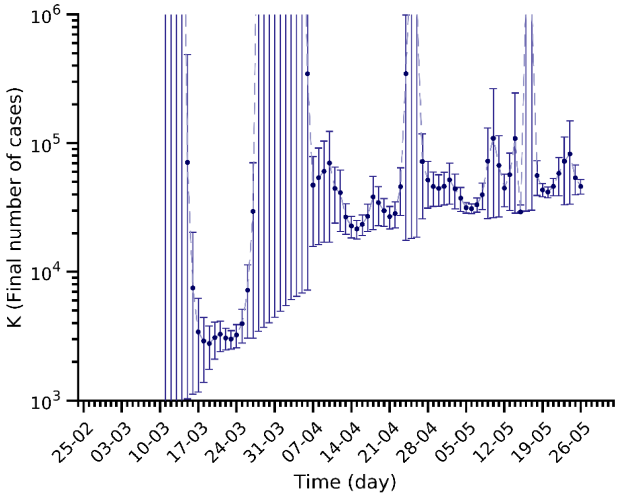



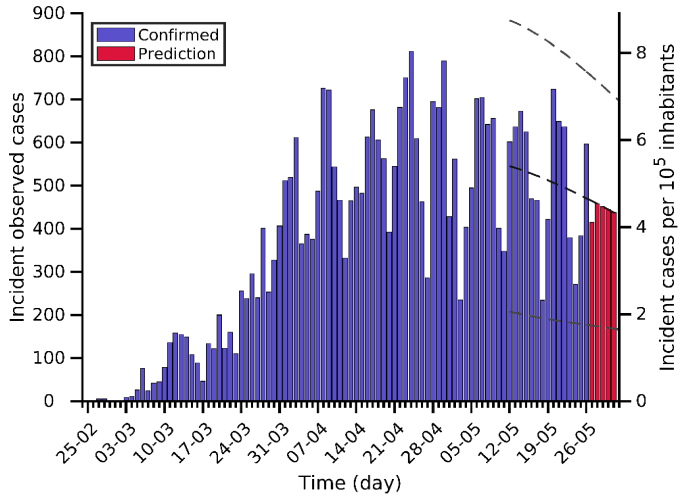
# Sweden 26-05-2020. Population: 10.1M. Current cumulated incidence: 341/10⁵

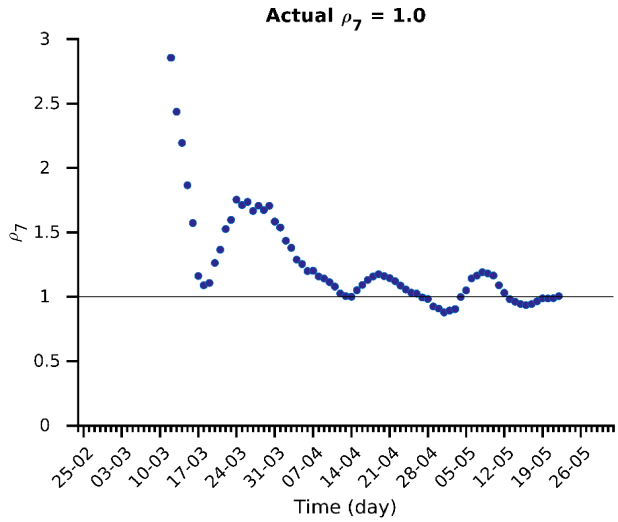


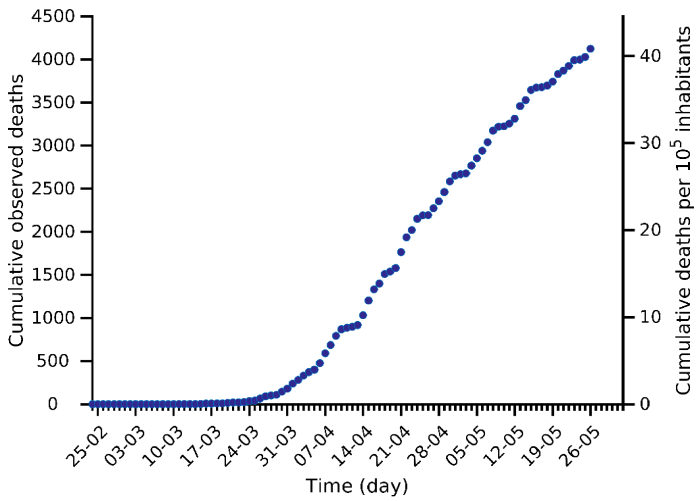



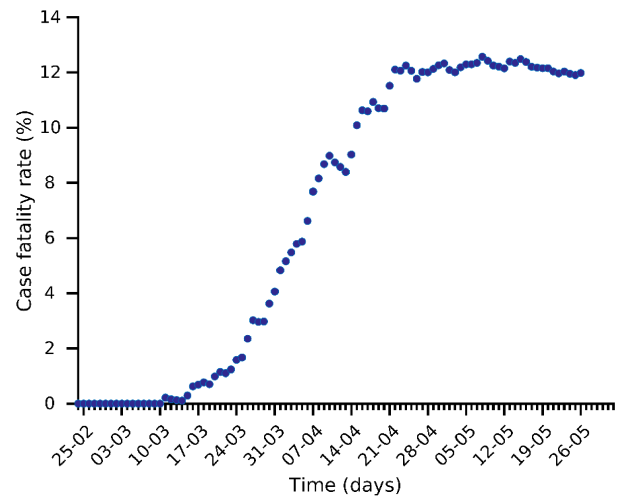



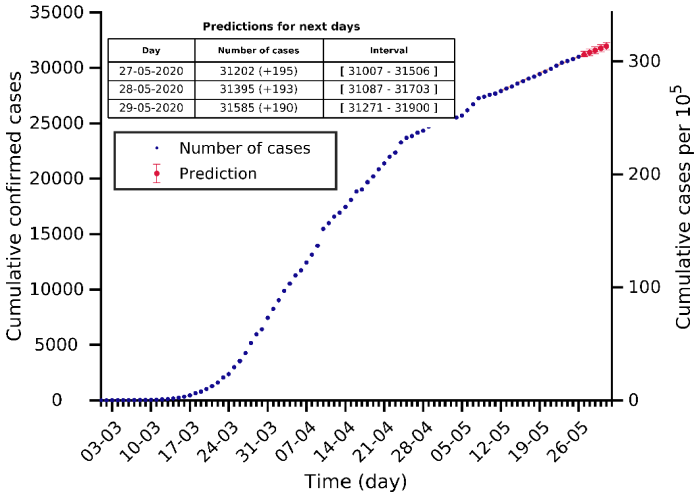



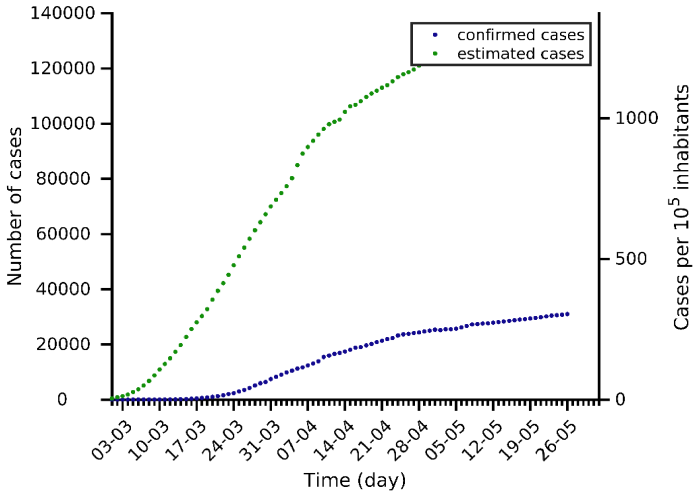



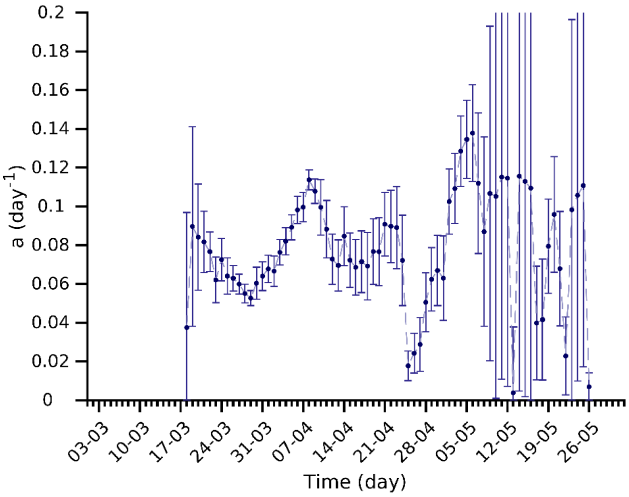



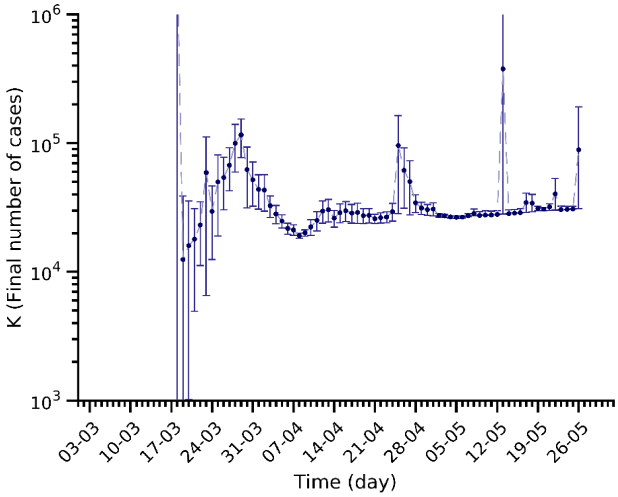



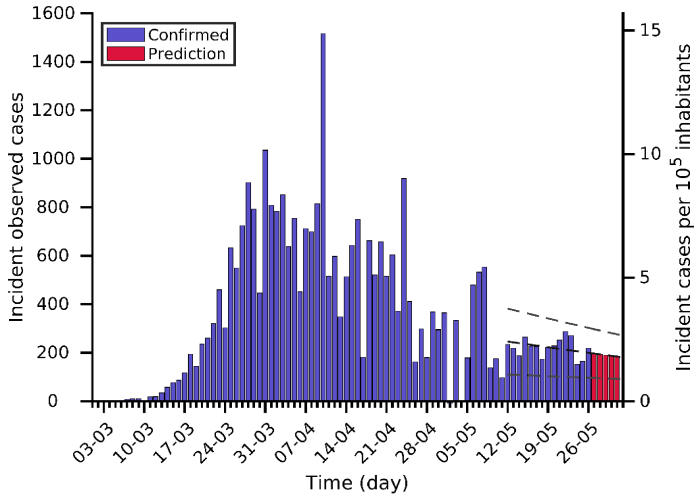
# Portugal 26-05-2020. Population: 10.2M. Current cumulated incidence: 304/10⁵

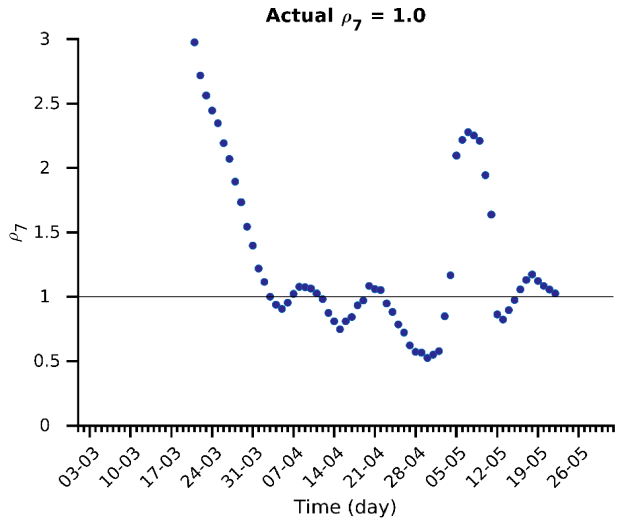


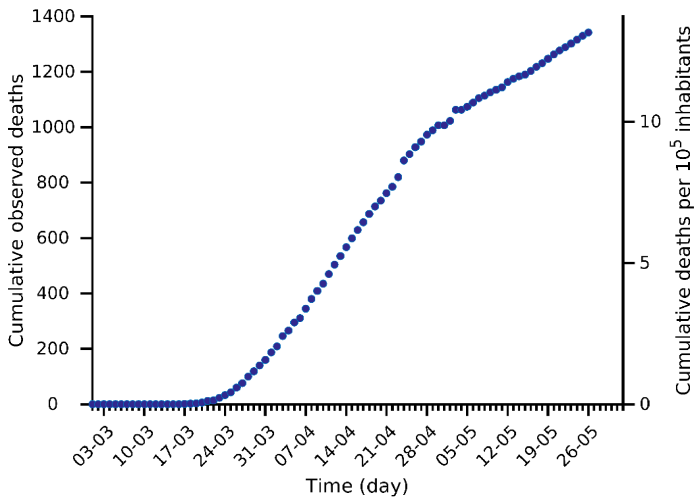



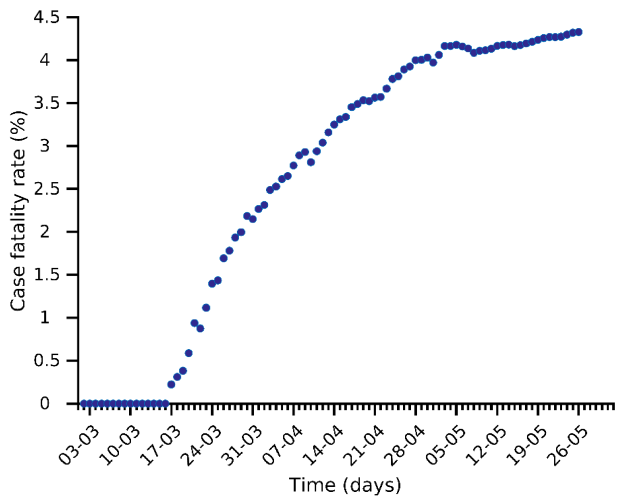



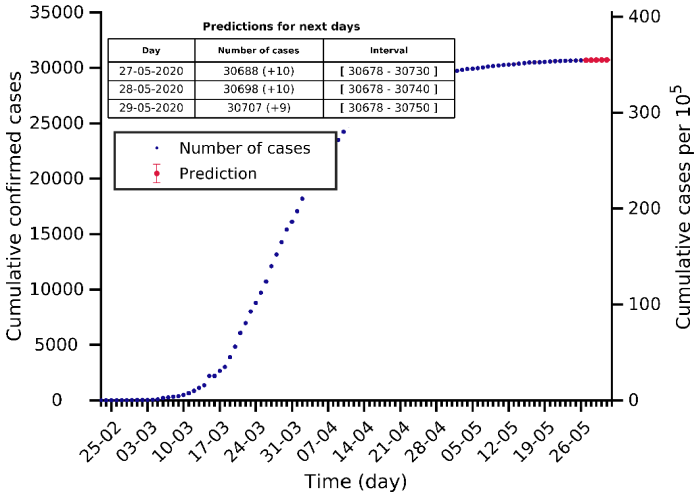



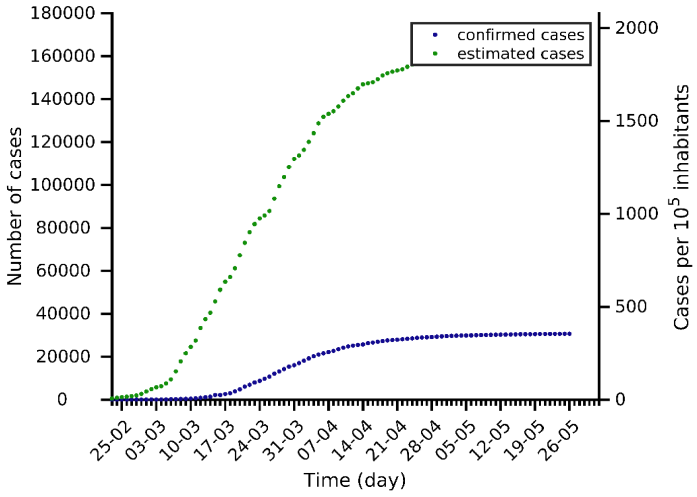



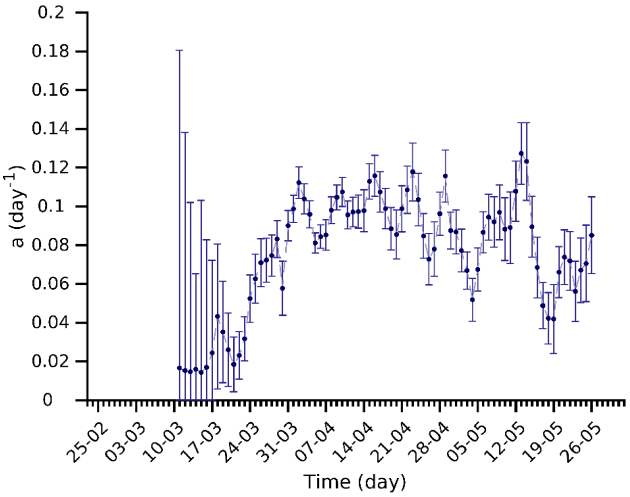



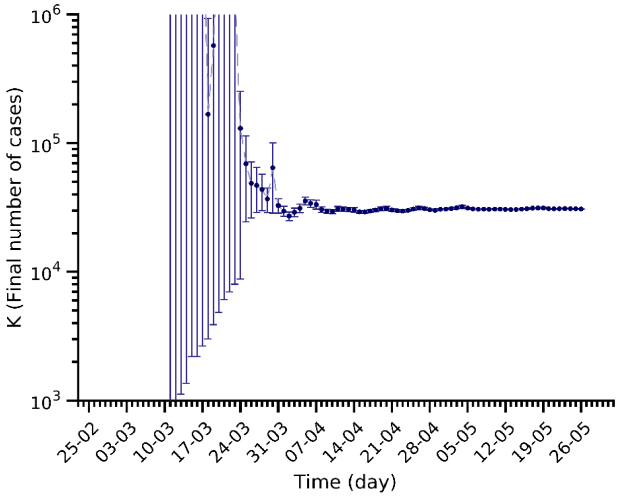



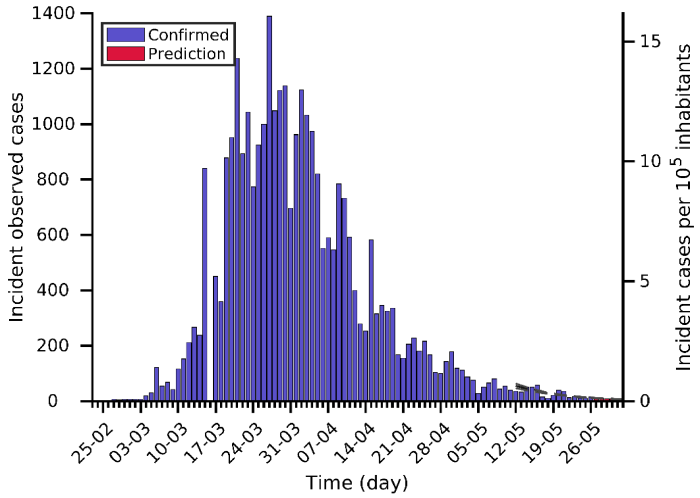
# Switzerland 26-05-2020. Population: 8.7M. Current cumulated incidence: 354/$10^5$

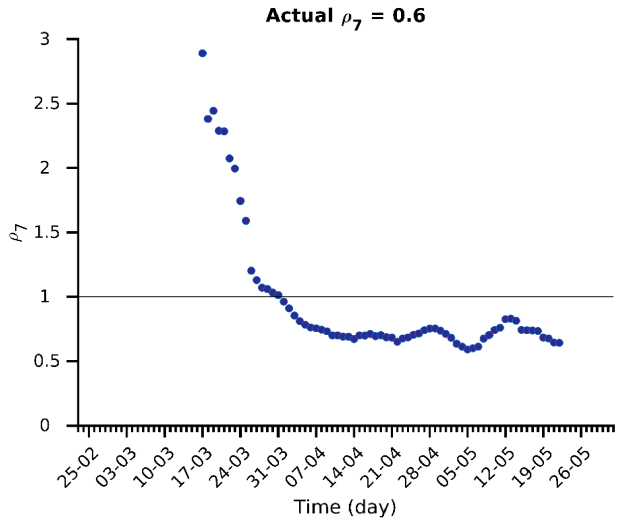


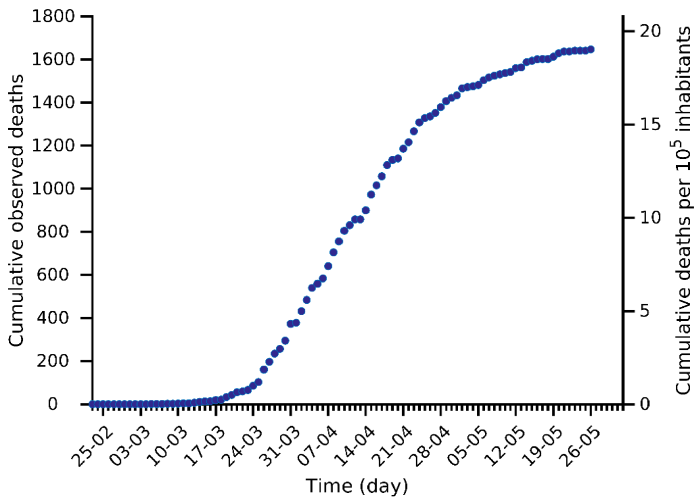



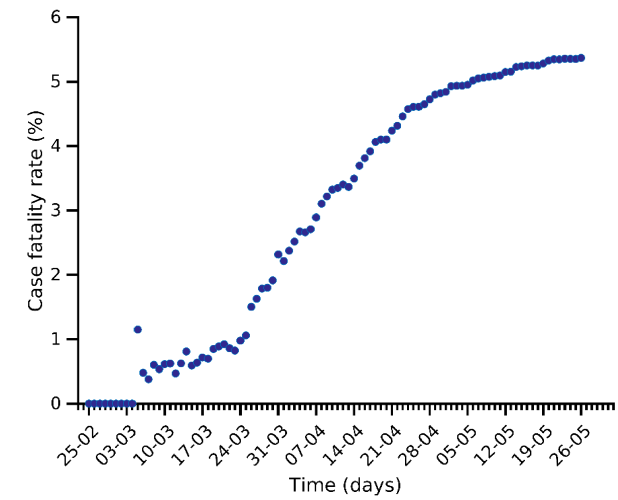



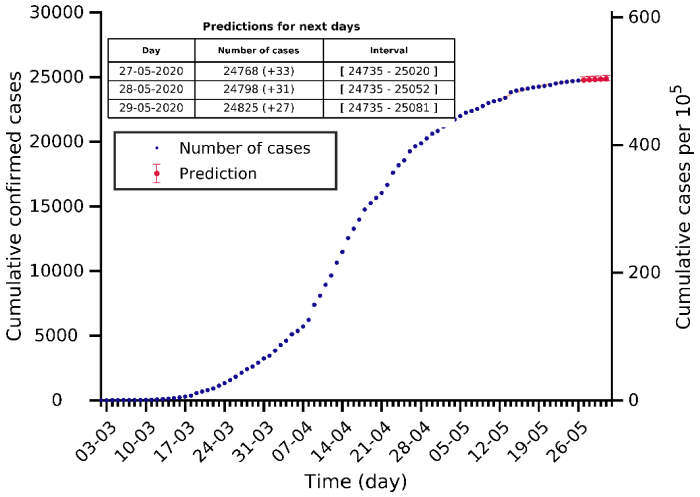



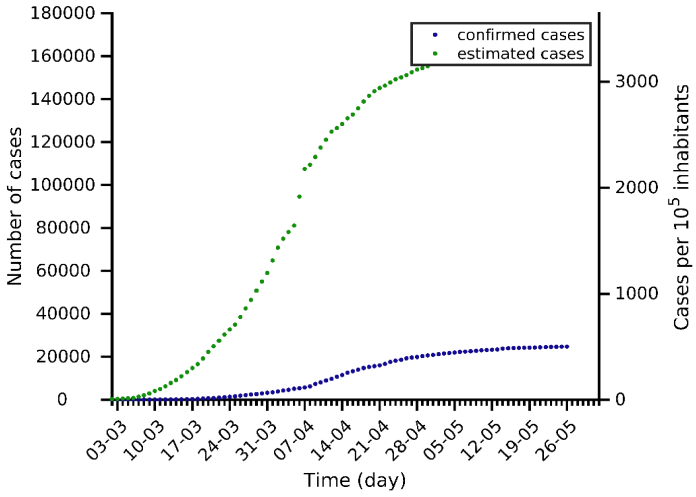



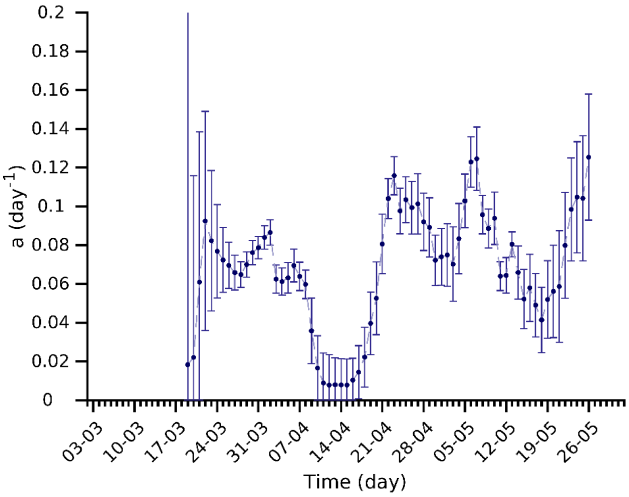



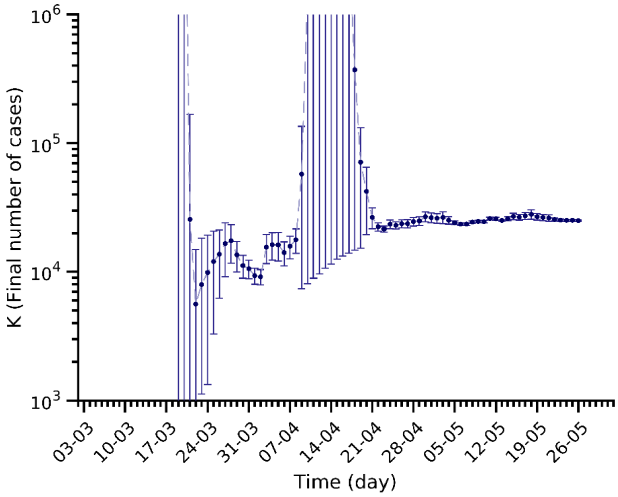



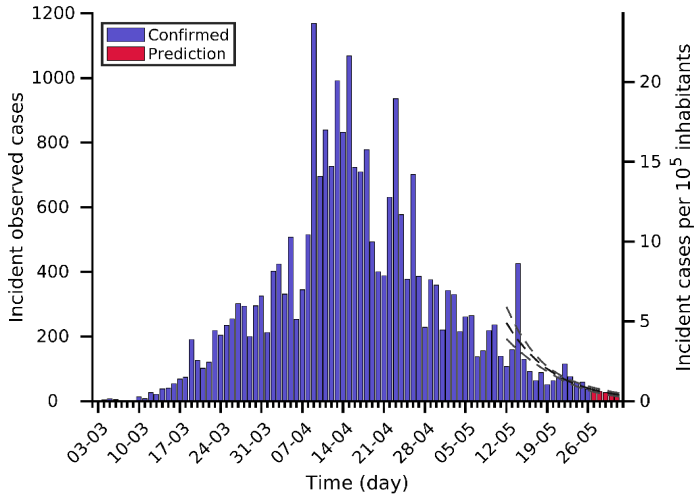
# Ireland 26-05-2020. Population: 4.9M. Current cumulated incidence: 501/$10^5$

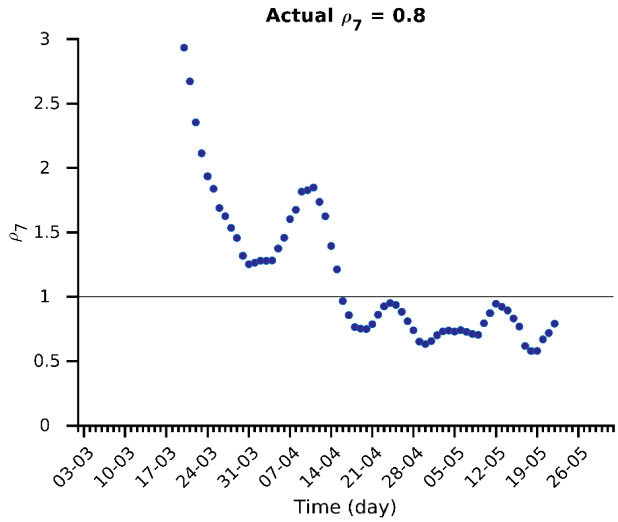


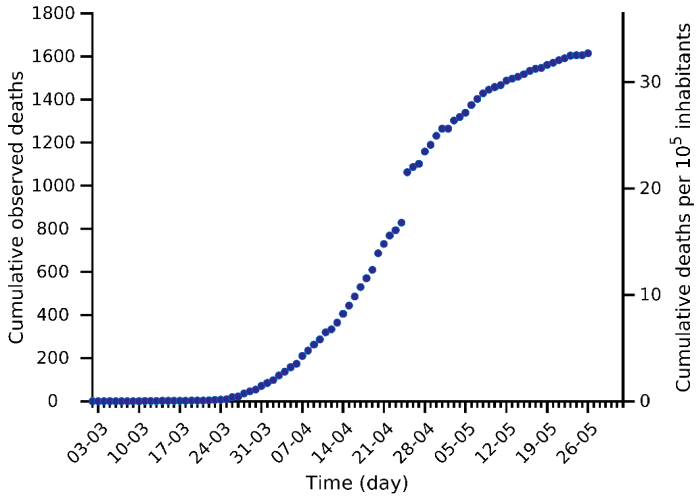



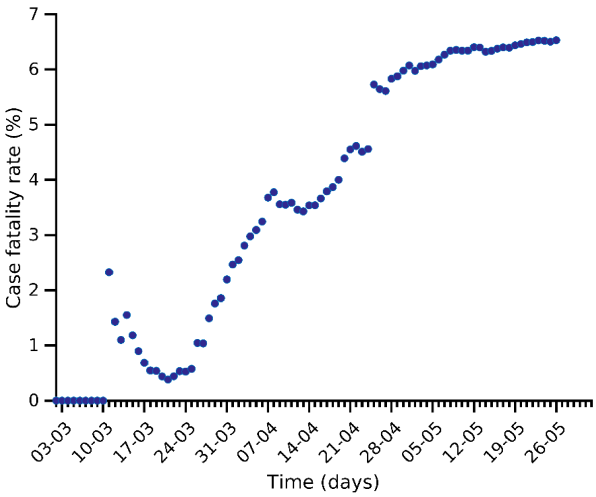



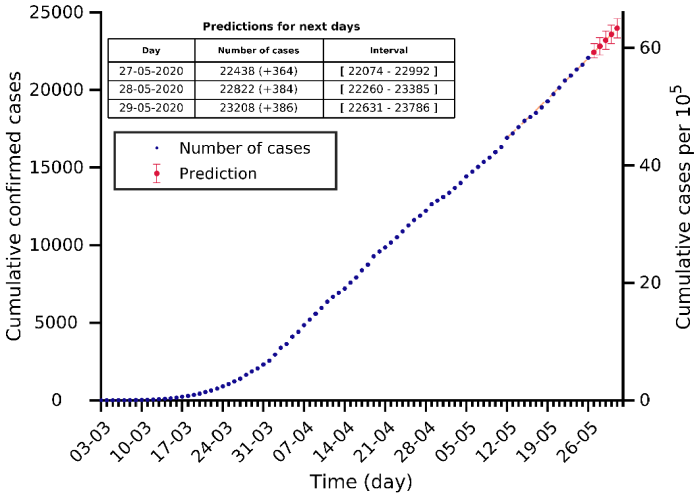



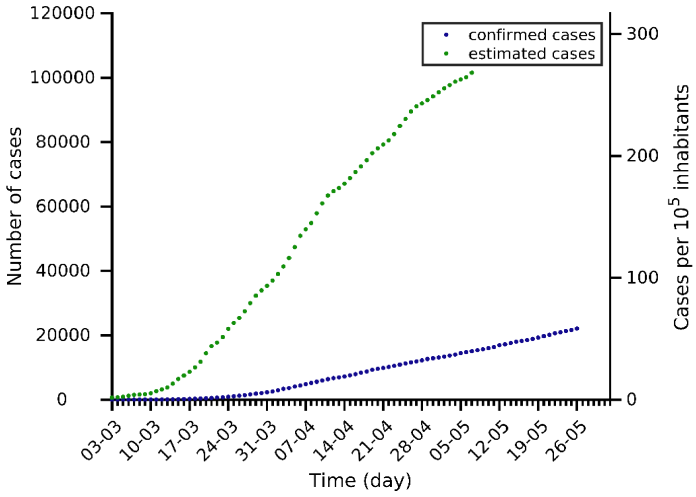



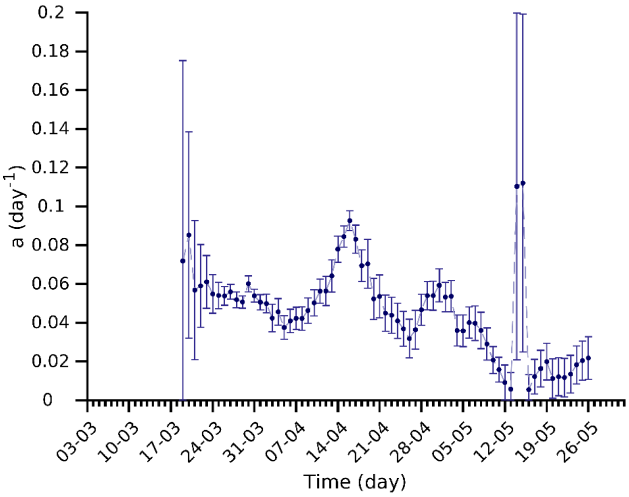



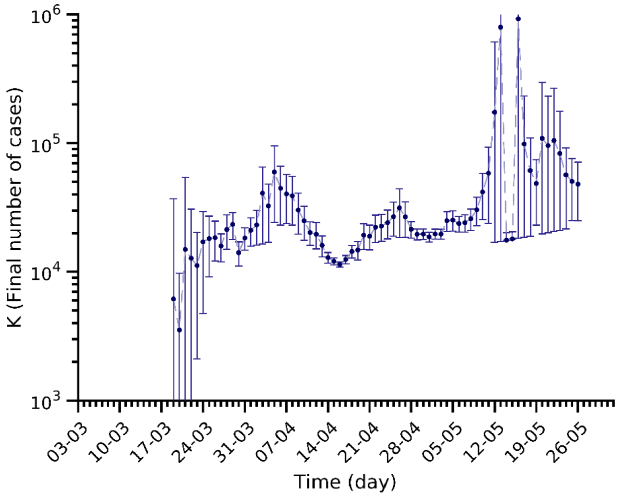



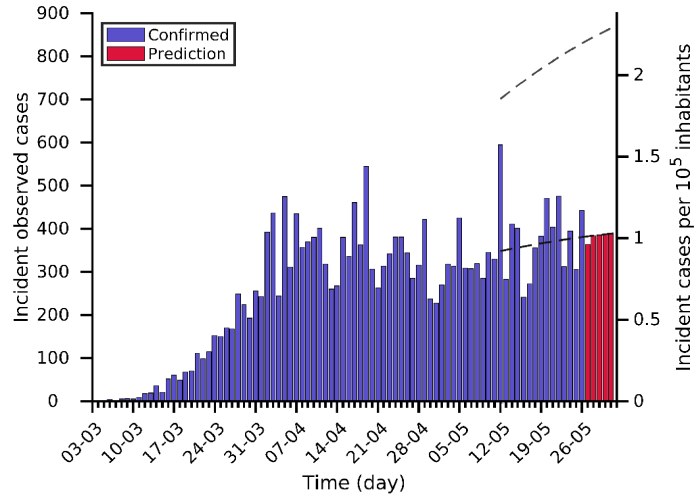
# Poland 26-05-2020. Population: 37.8M. Current cumulated incidence: $58/10^5$

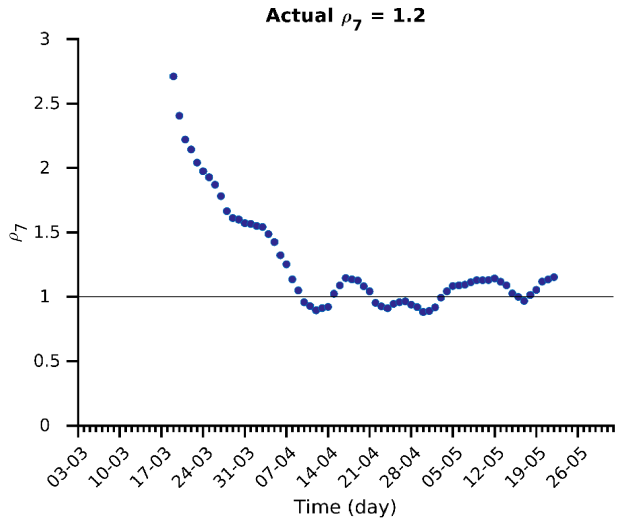


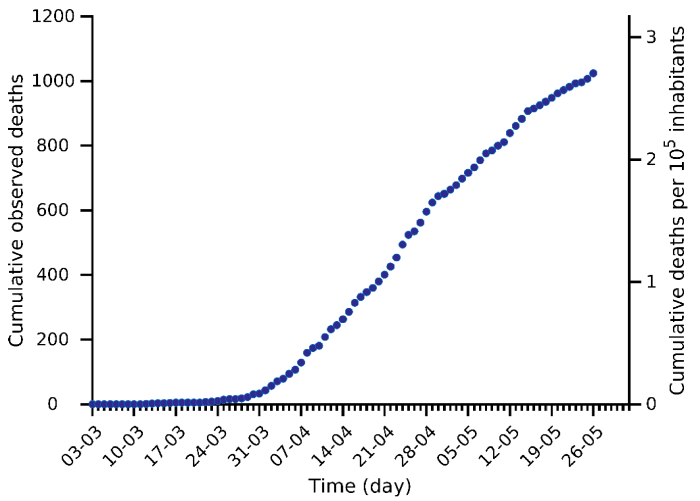



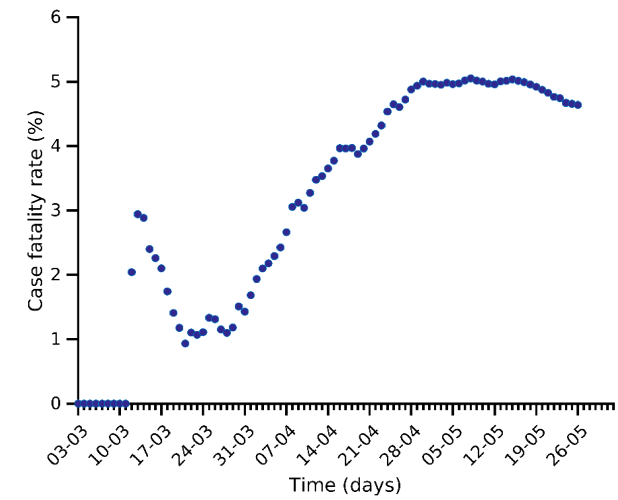



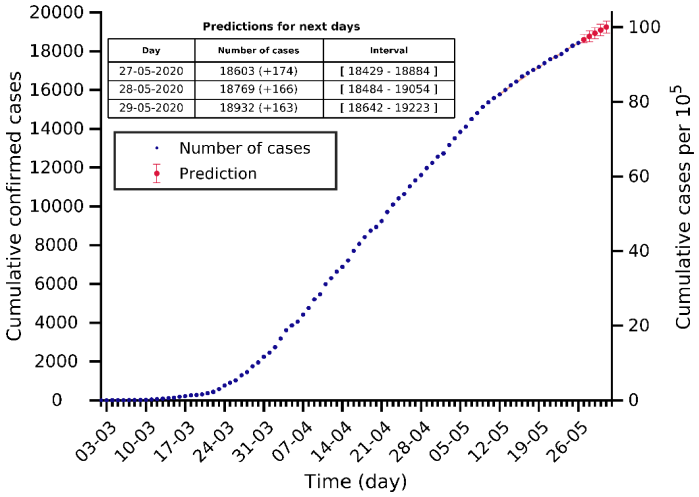



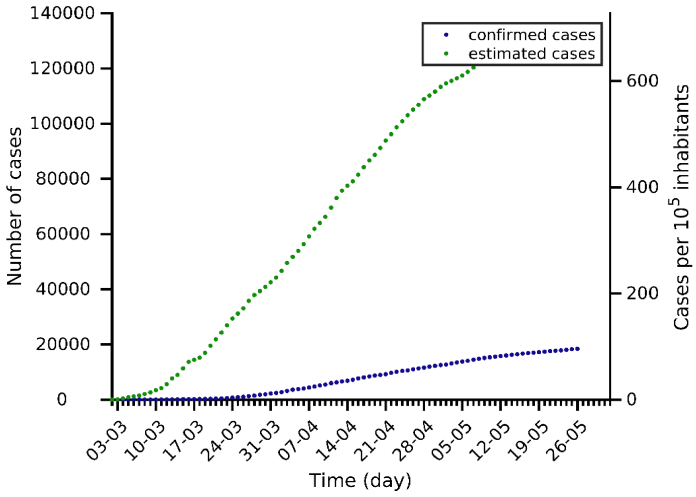



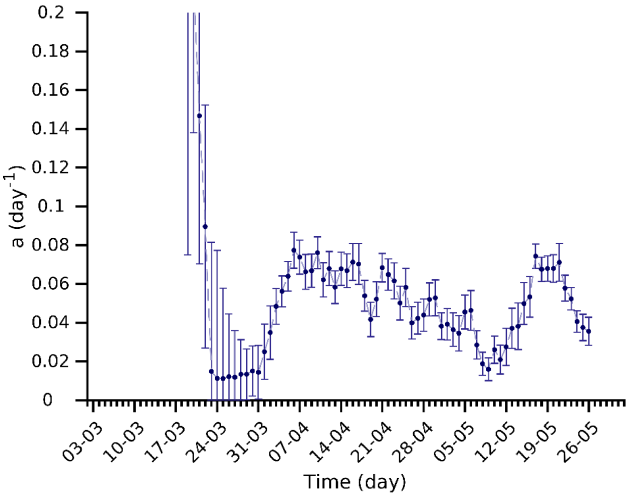



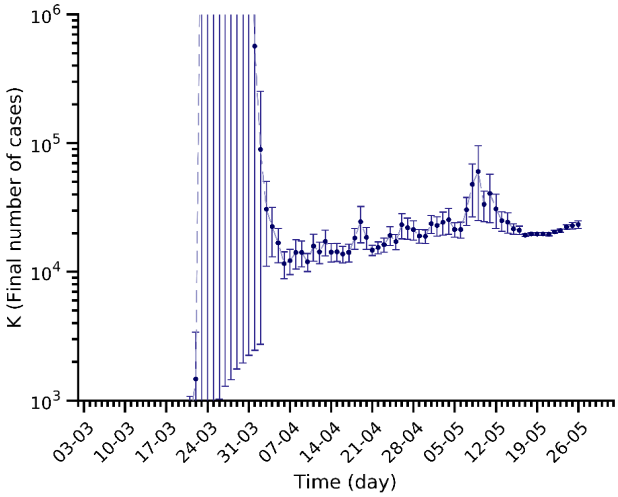



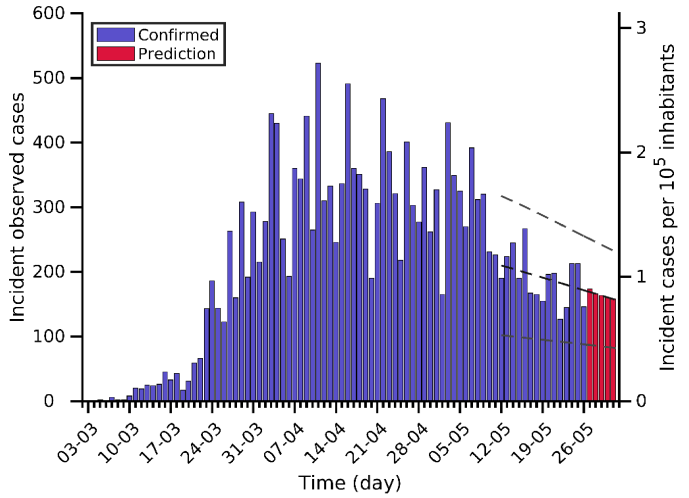
# Romania 26-05-2020. Population: 19.2M. Current cumulated incidence: 96/$10^5$

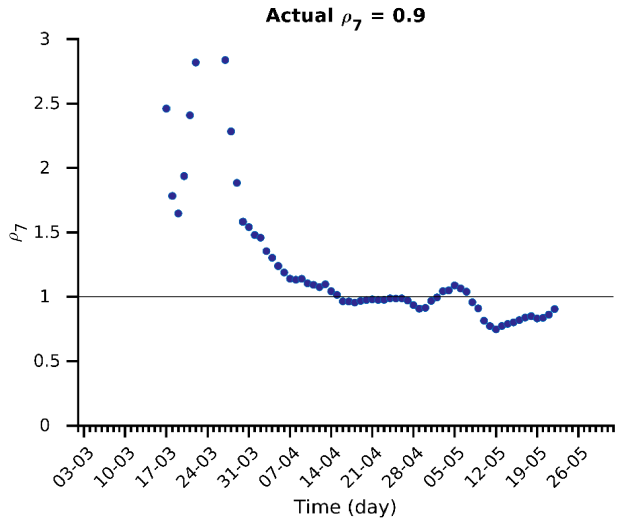


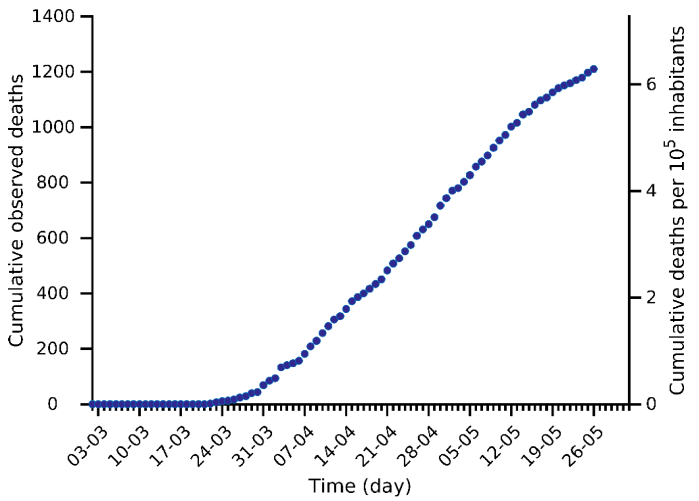



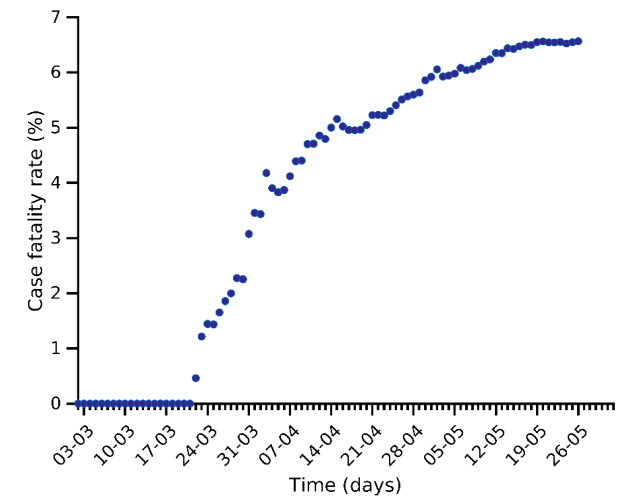



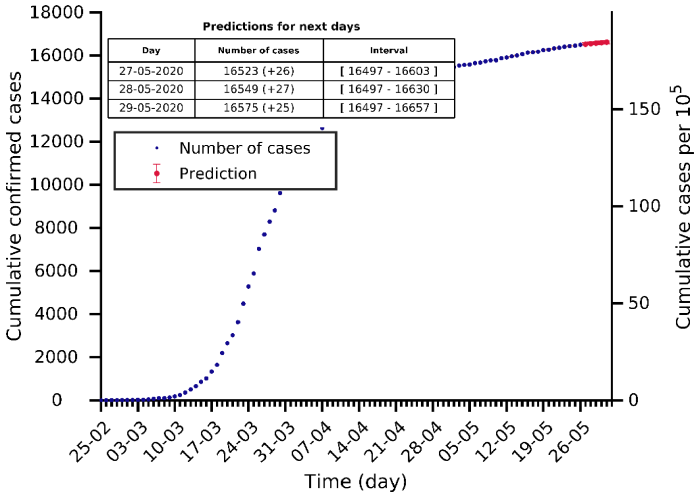



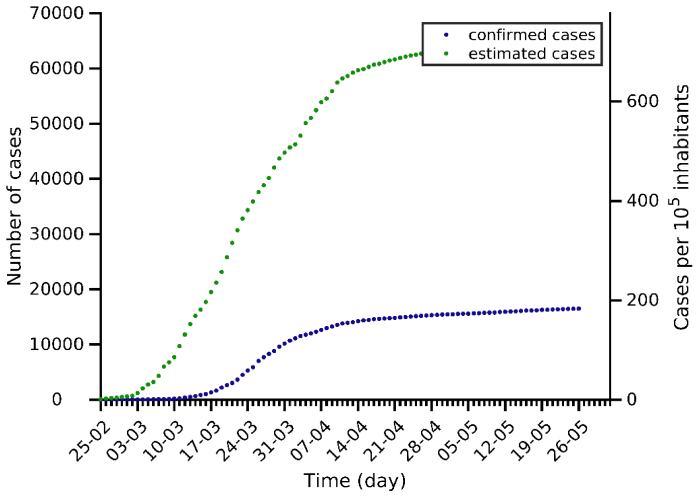



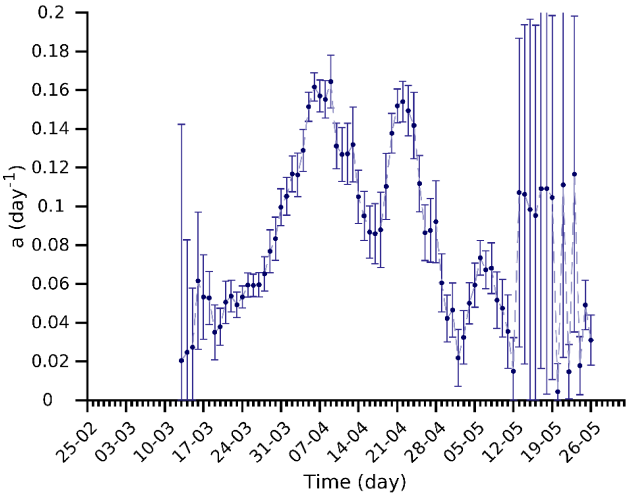



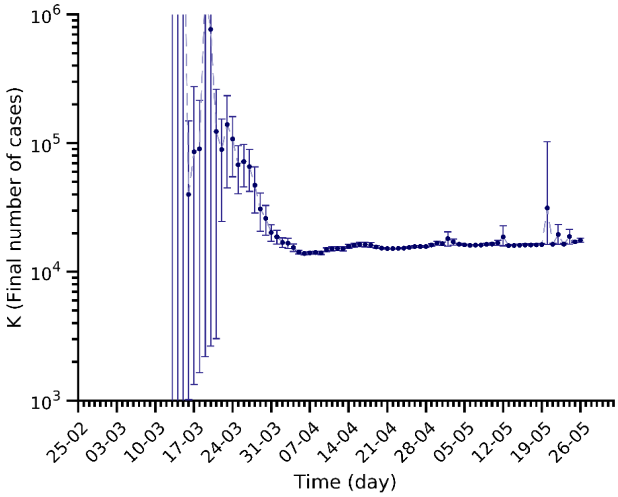



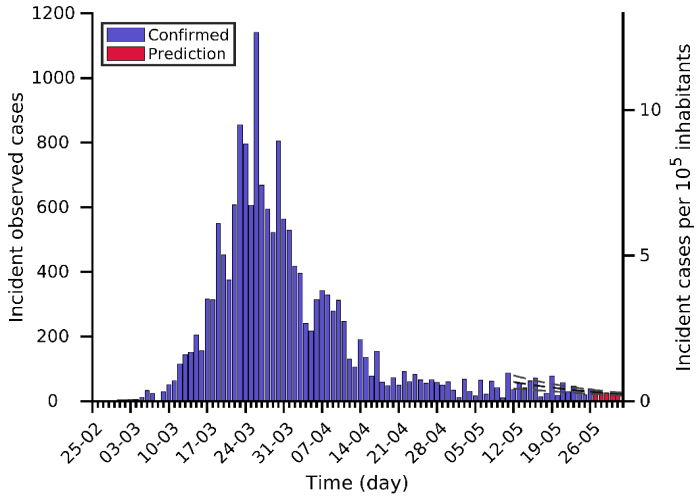
# Austria 26-05-2020. Population: 9.0M. Current cumulated incidence: $183/10^5$

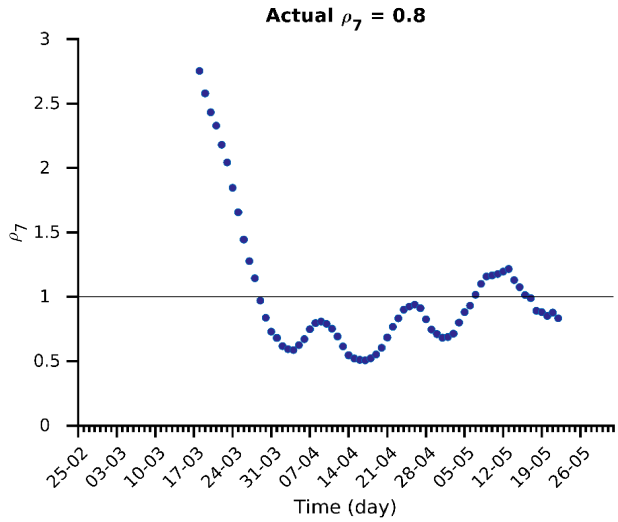


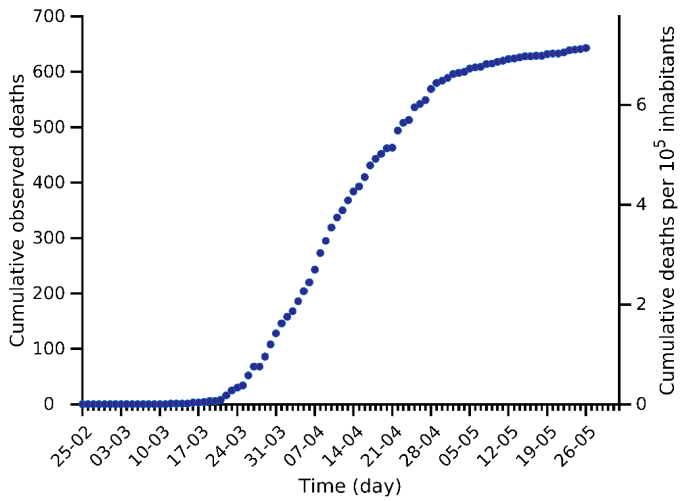



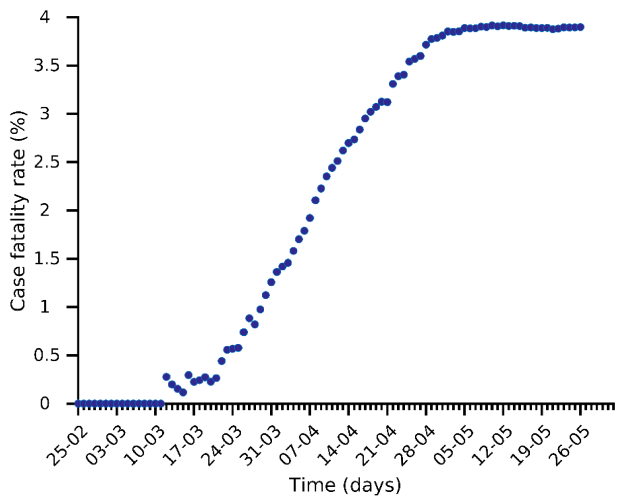



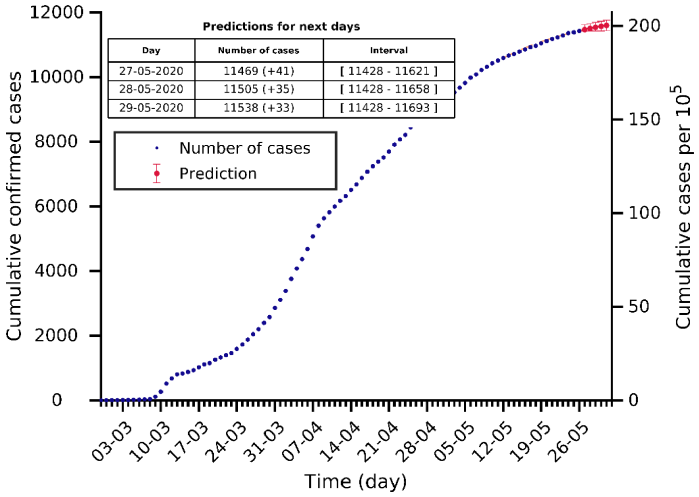



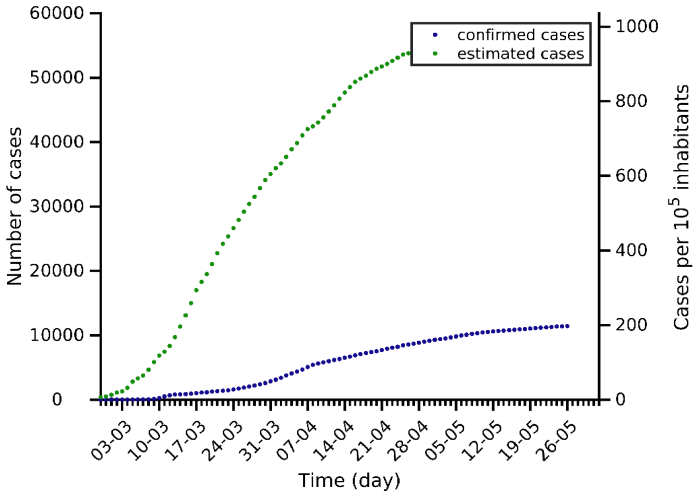



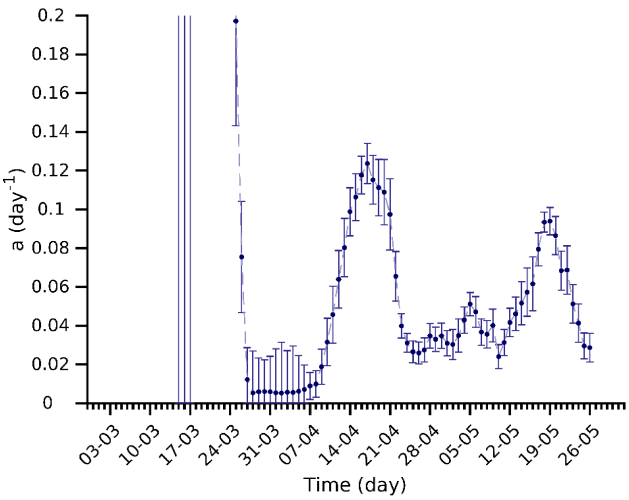



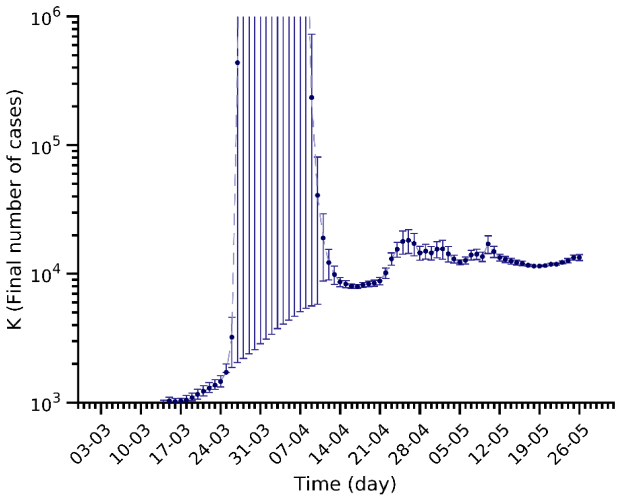



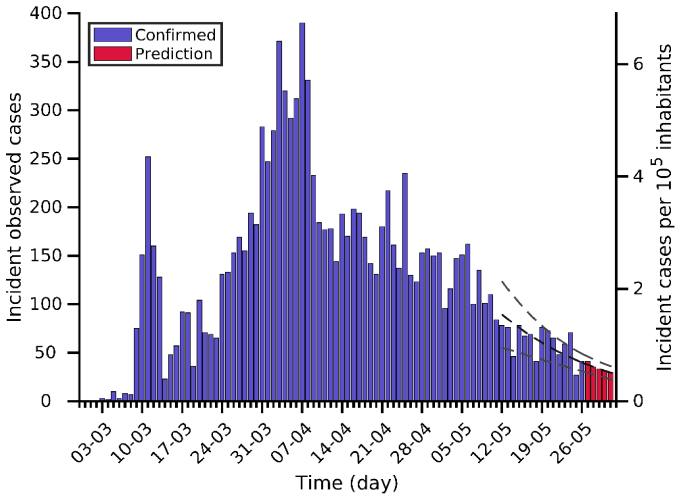
# Denmark 26-05-2020. Population: 5.8M. Current cumulated incidence: 197/10⁵

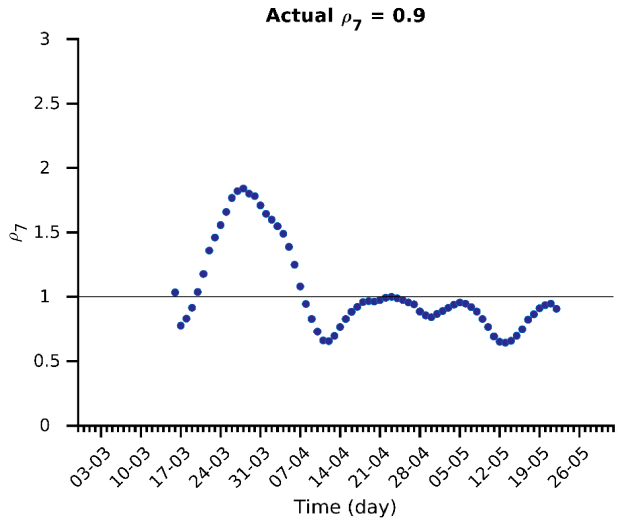


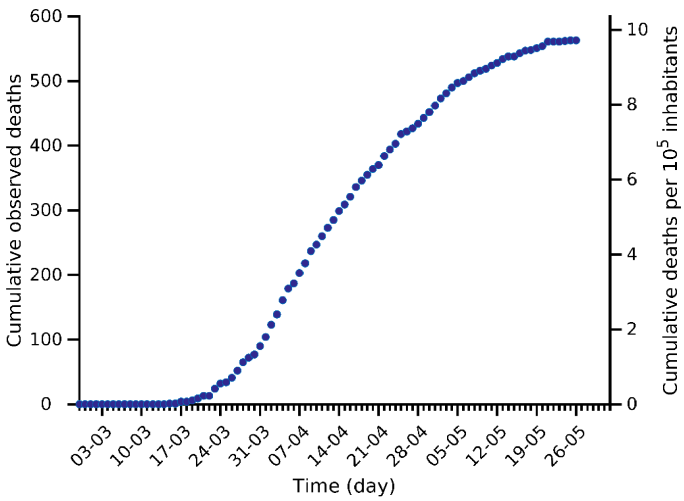



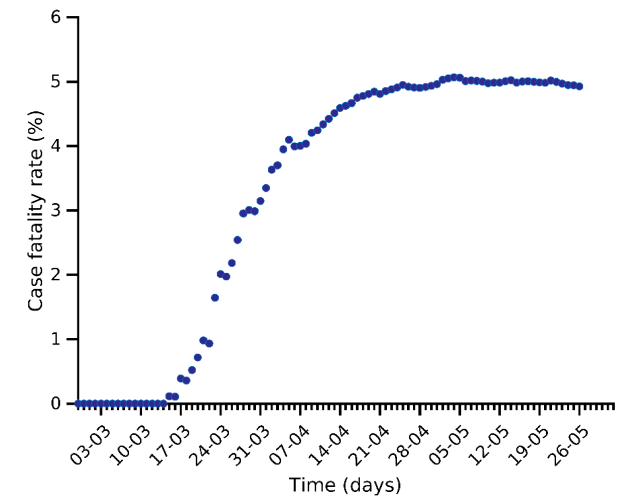



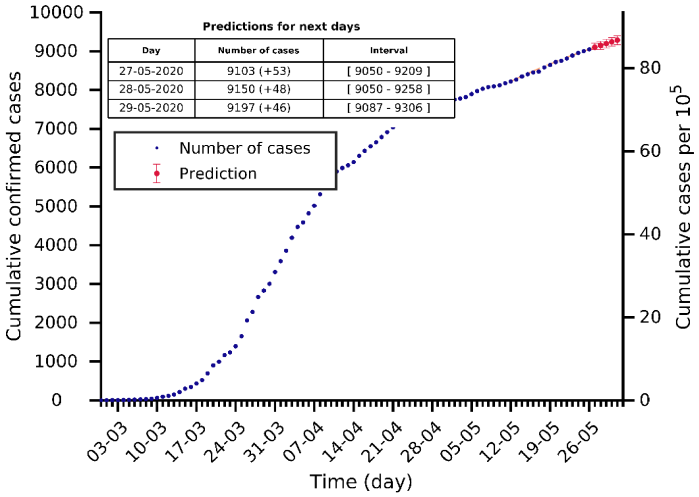



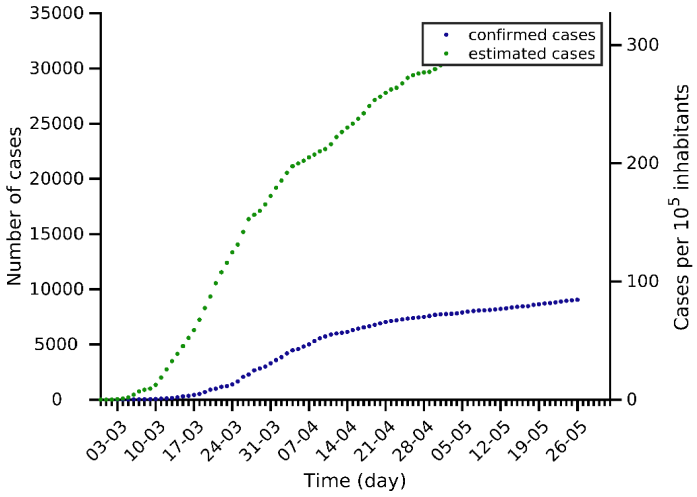



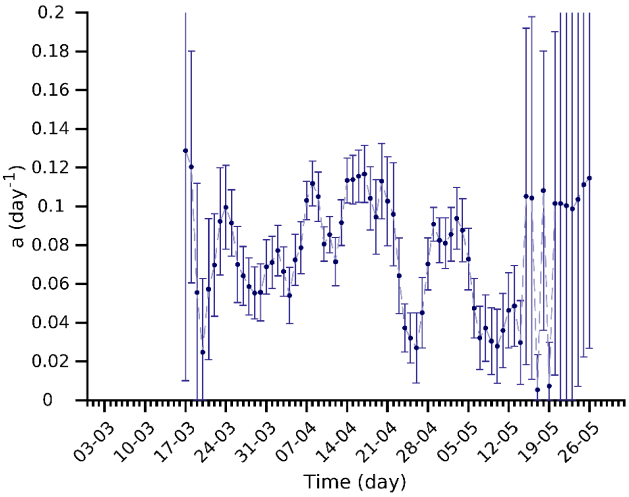



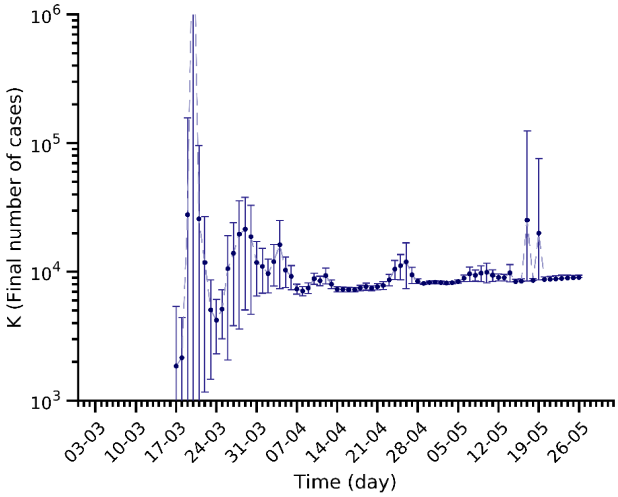



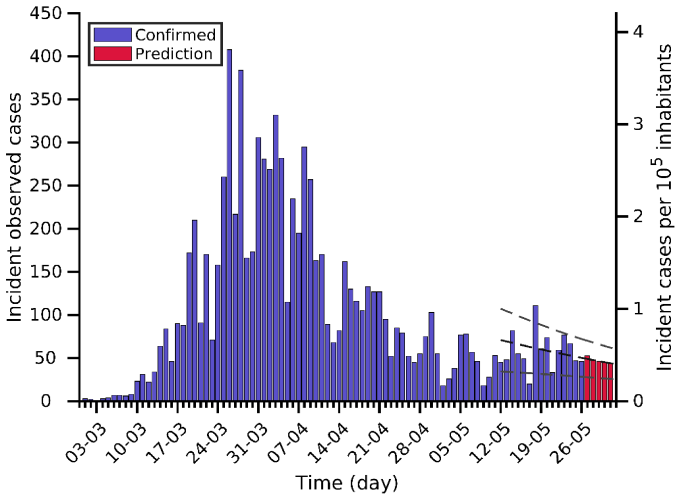
# Czech Rep 26-05-2020. Population: 10.7M. Current cumulated incidence: 85/$10^5$

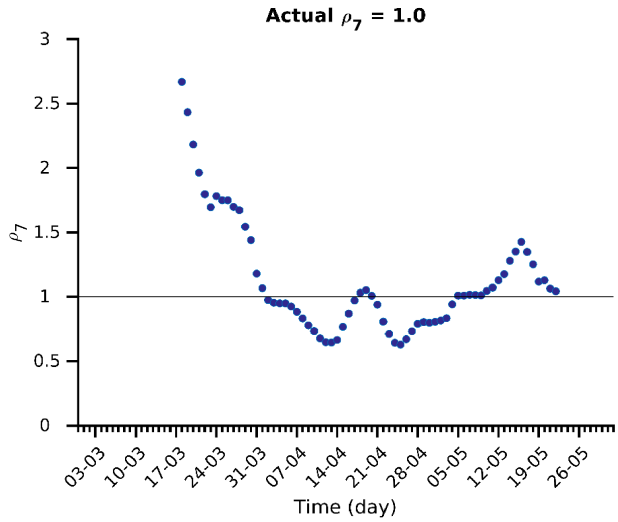


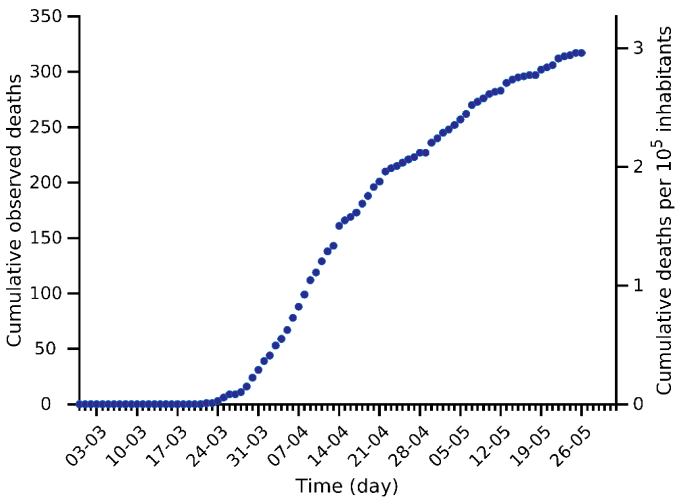



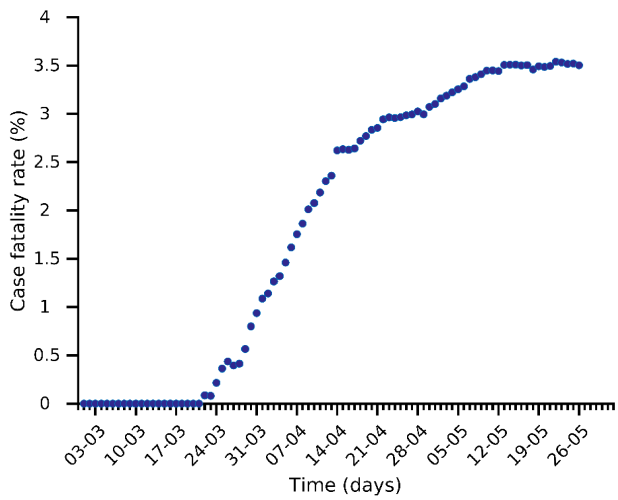



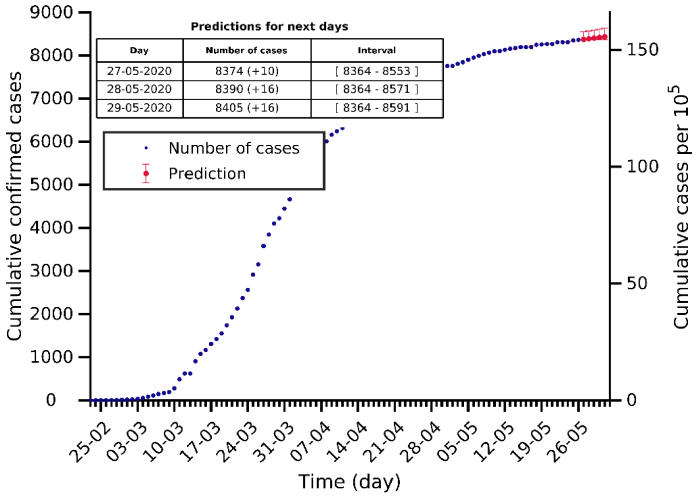



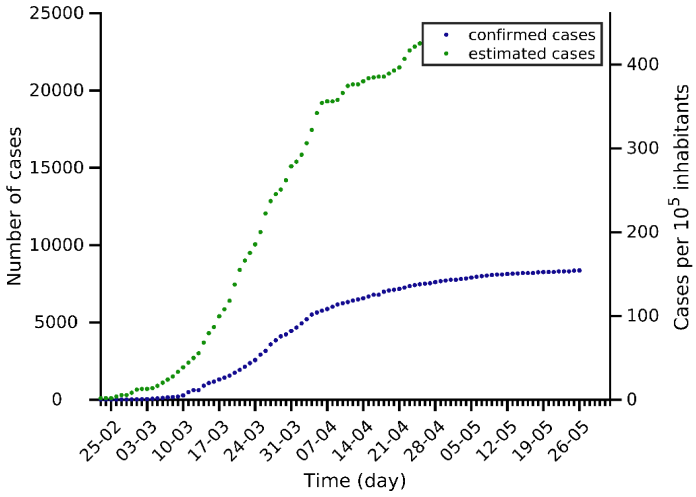



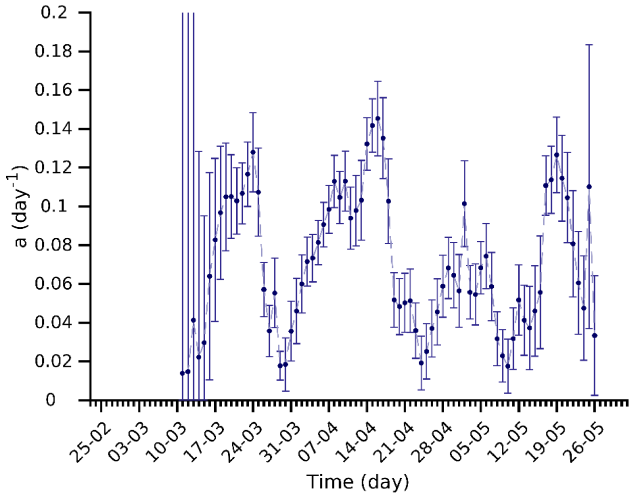



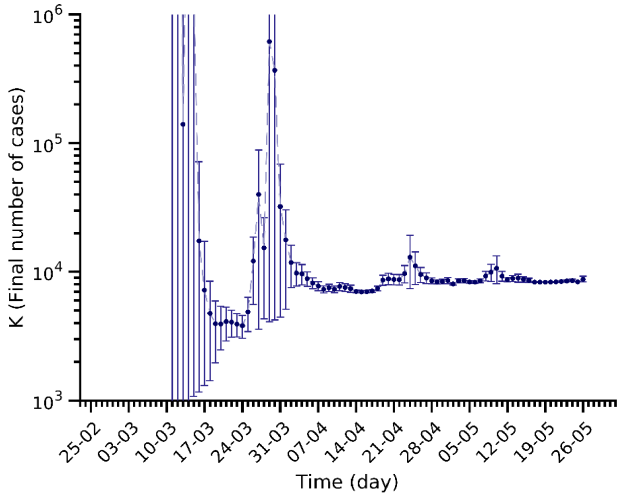



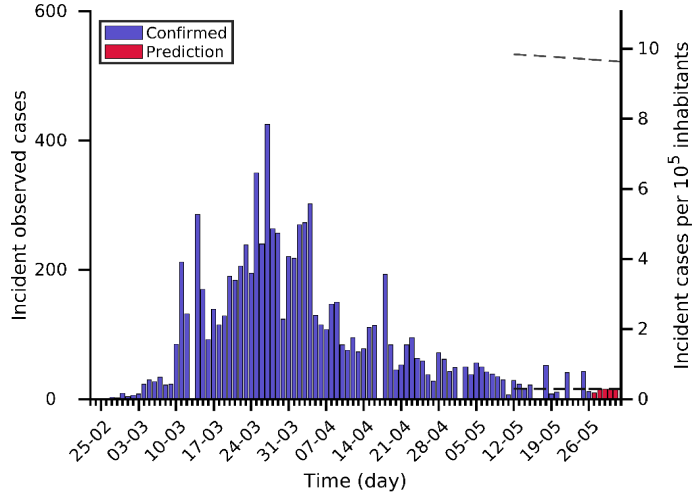
# Norway 26-05-2020. Population: 5.4M. Current cumulated incidence: 154/$10^5$

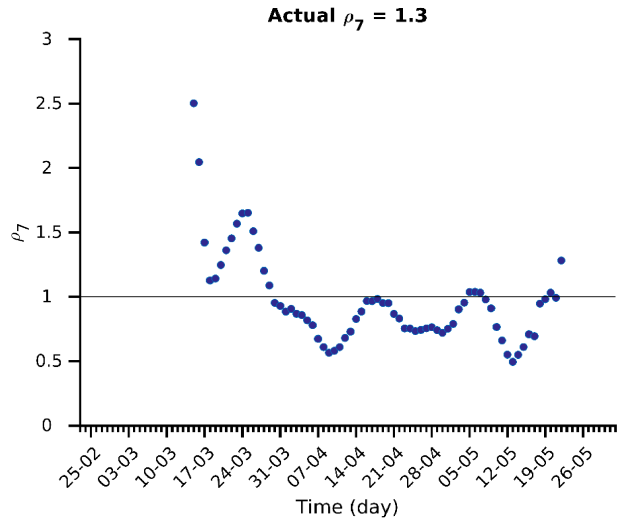


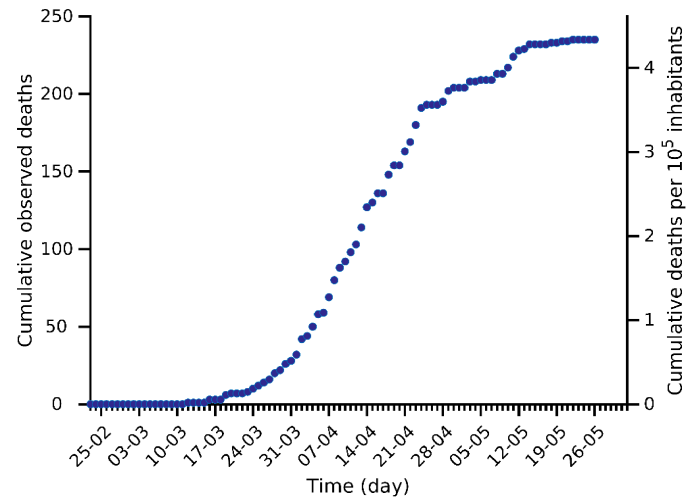



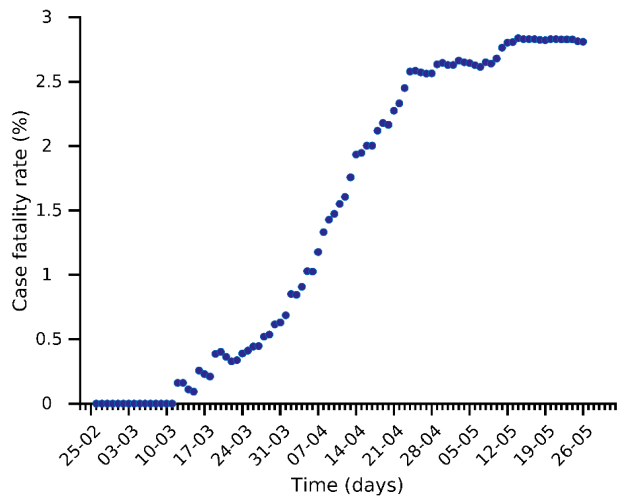



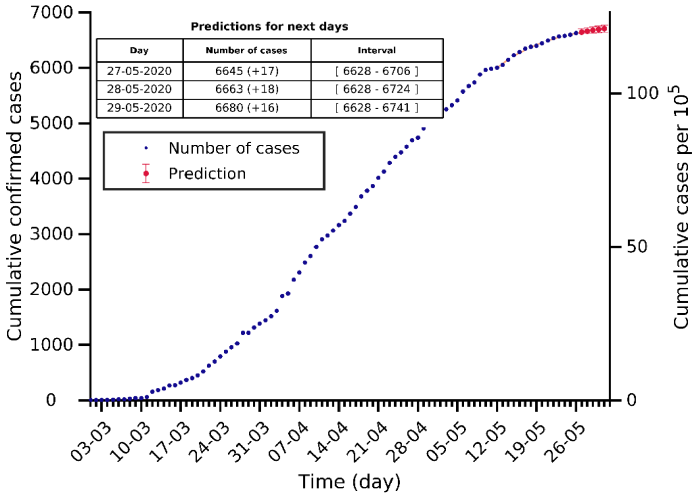



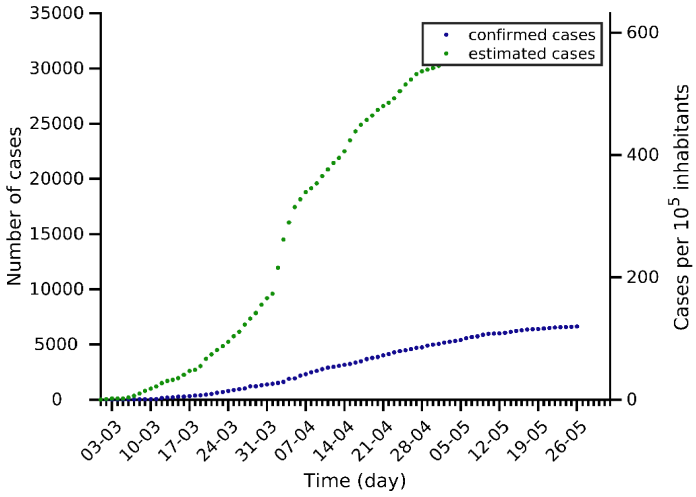



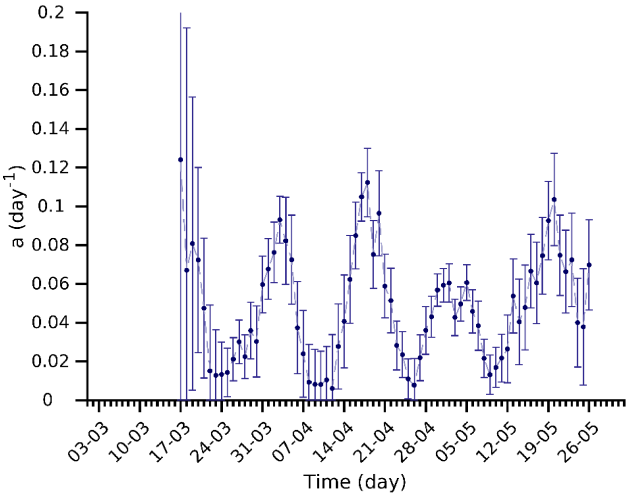



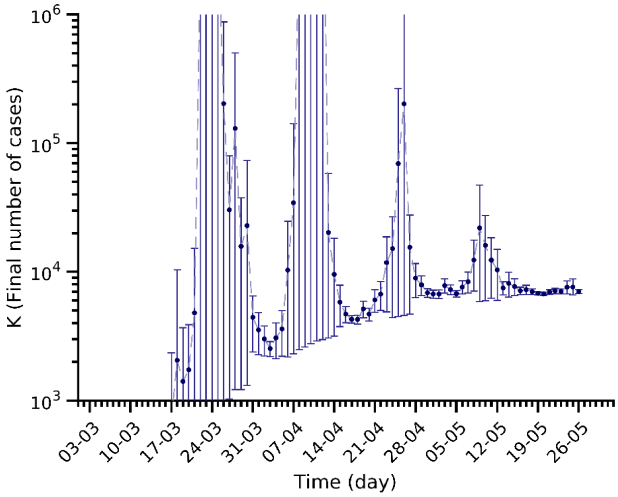



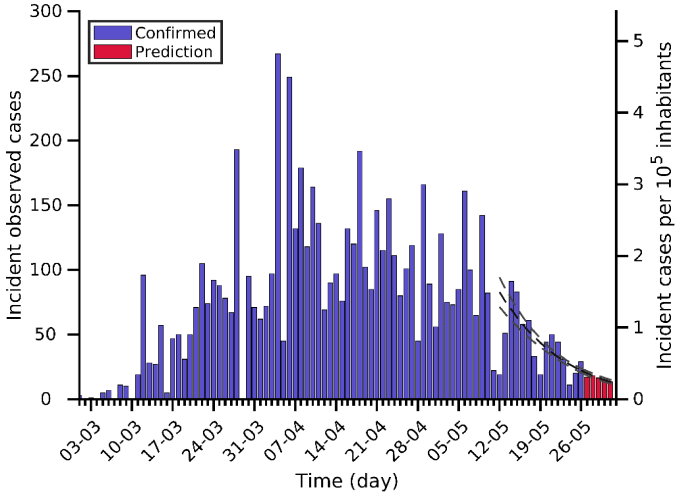
# Finland 26-05-2020. Population: 5.5M. Current cumulated incidence: 120/10⁵

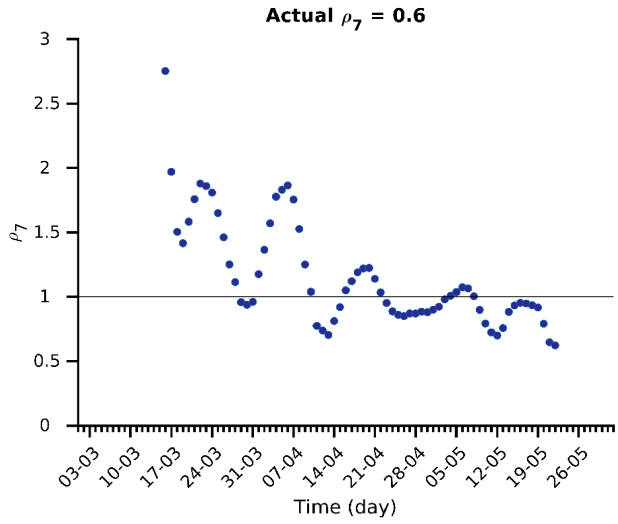


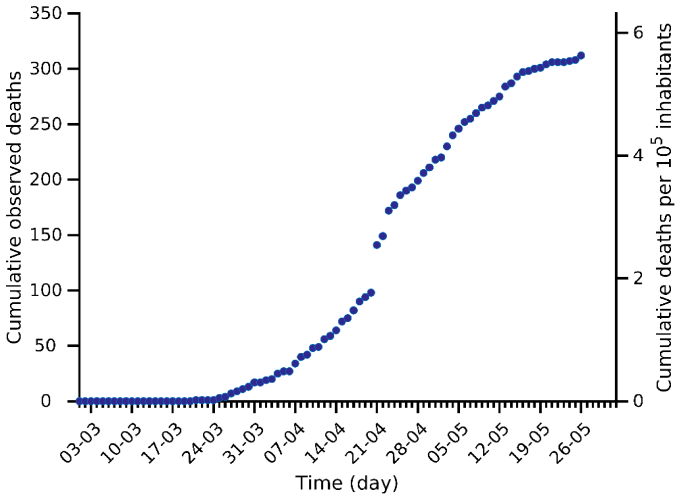



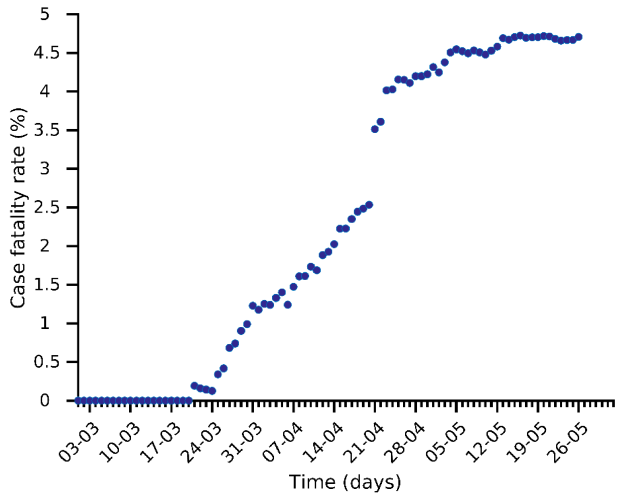



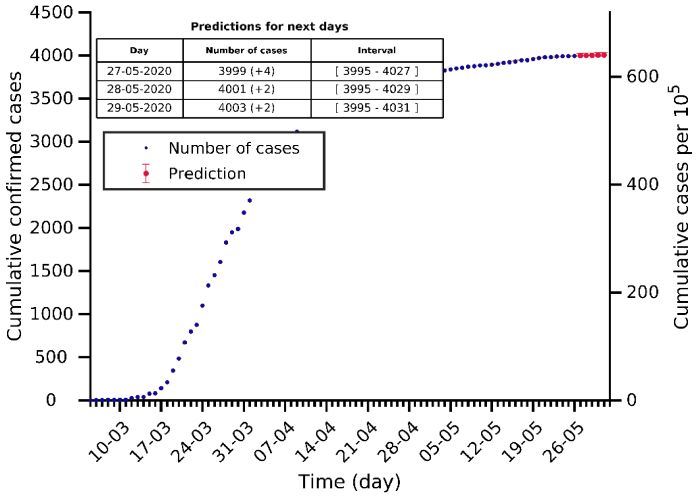



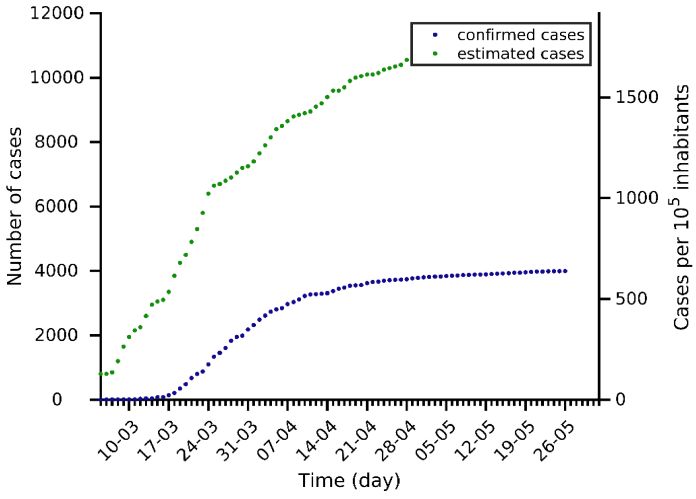



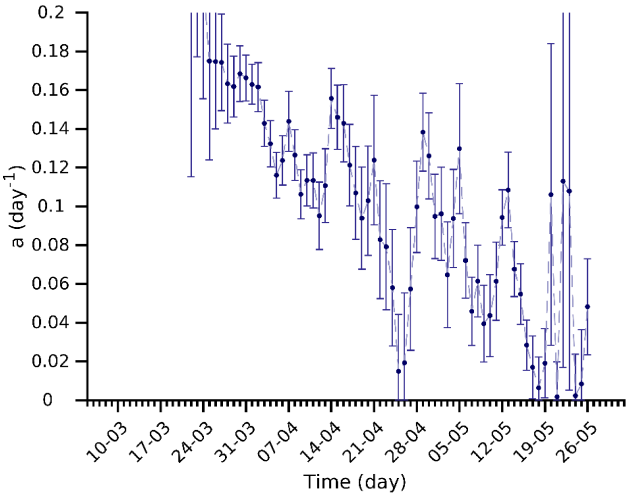



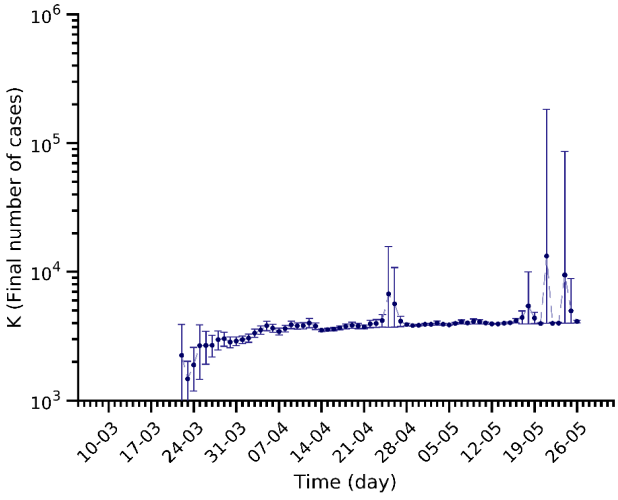



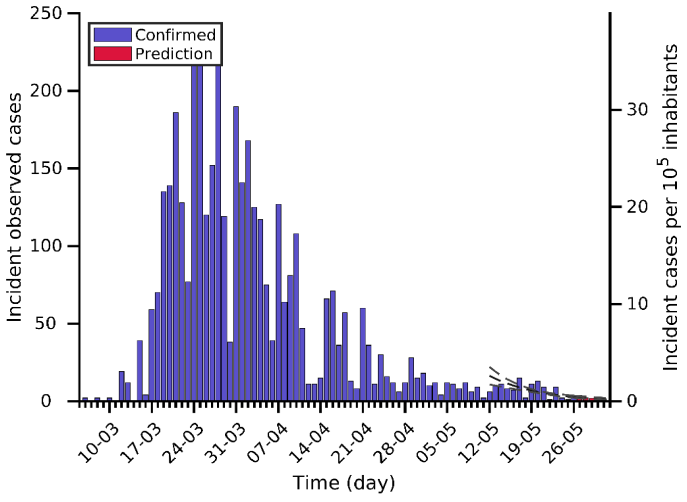
# Luxembourg 26-05-2020. Population: 0.6M. Current cumulated incidence: 638/$10^5$

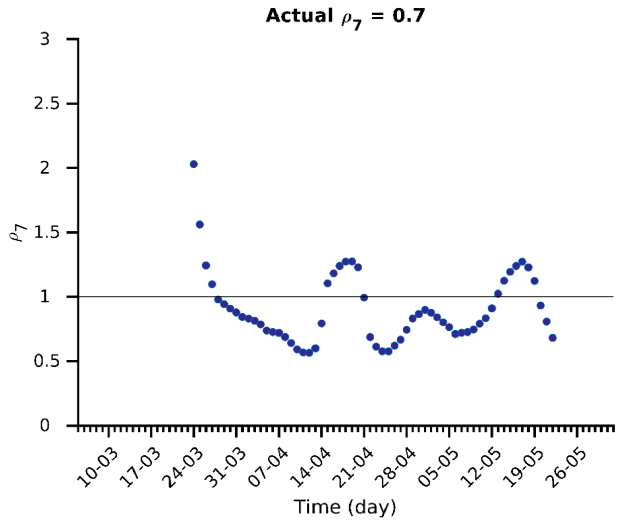


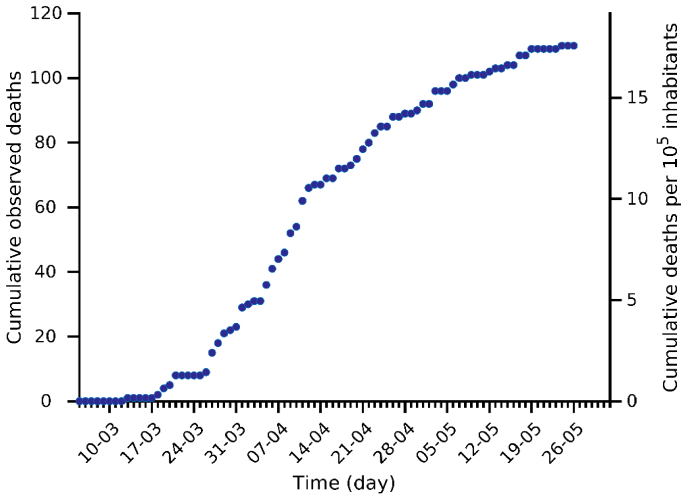



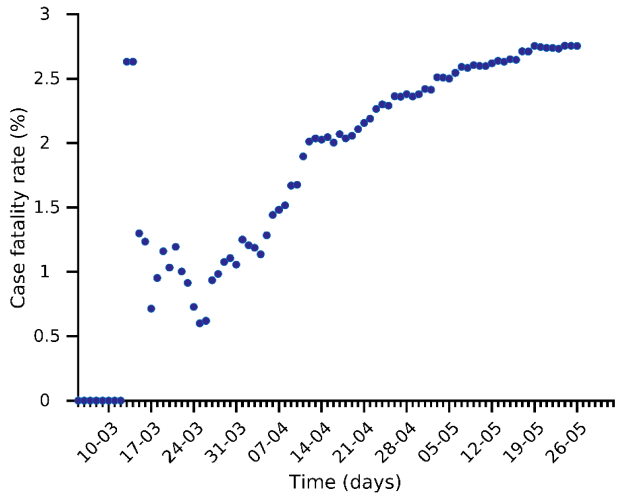



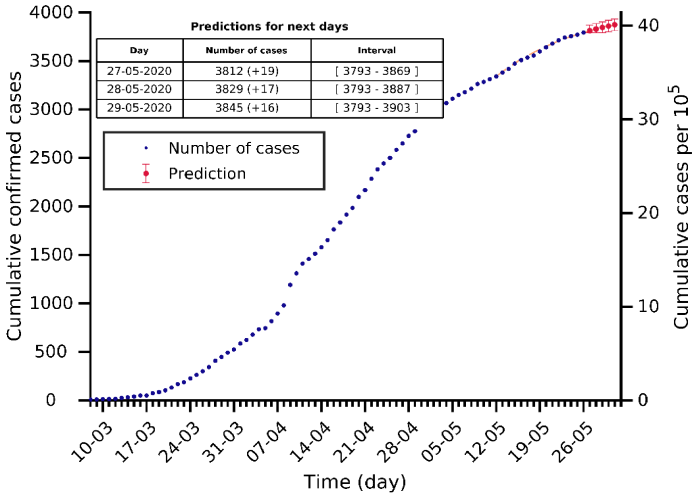



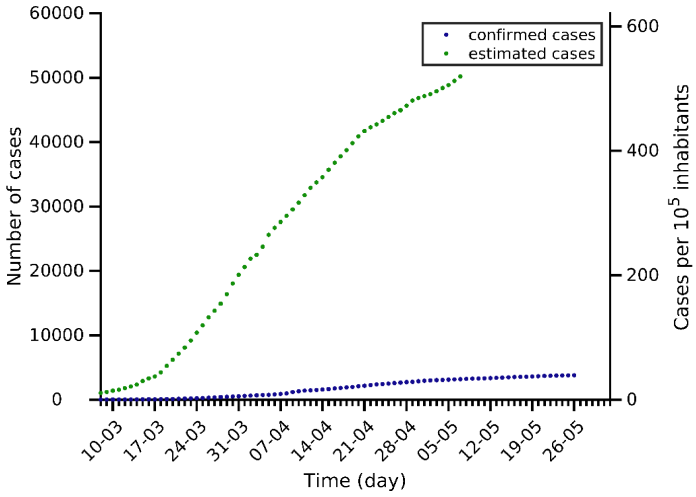



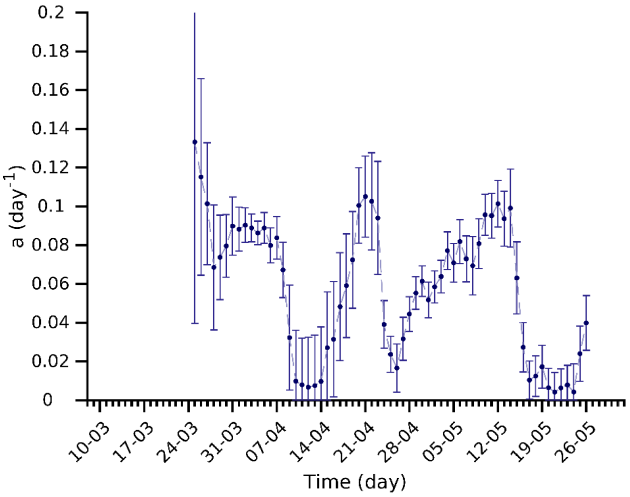



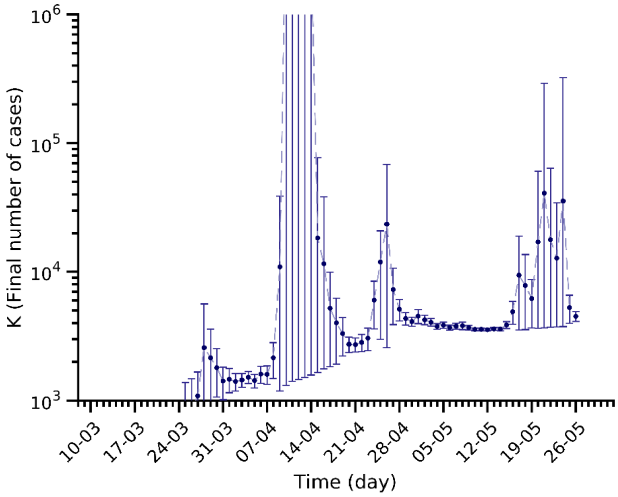



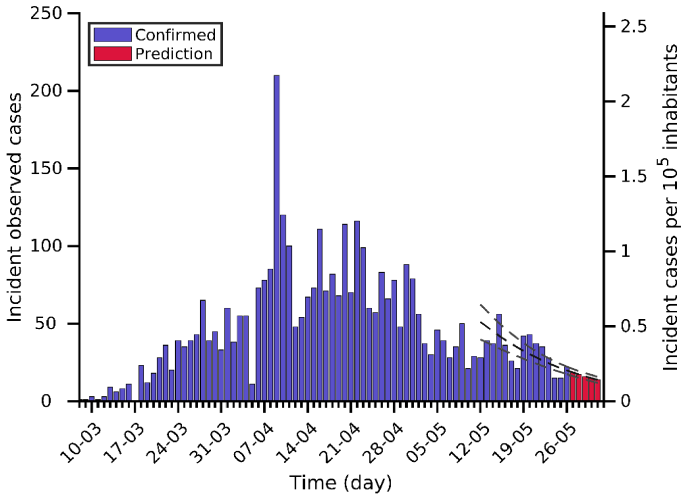
# Hungary 26-05-2020. Population: 9.7M. Current cumulated incidence: $39/10^5$

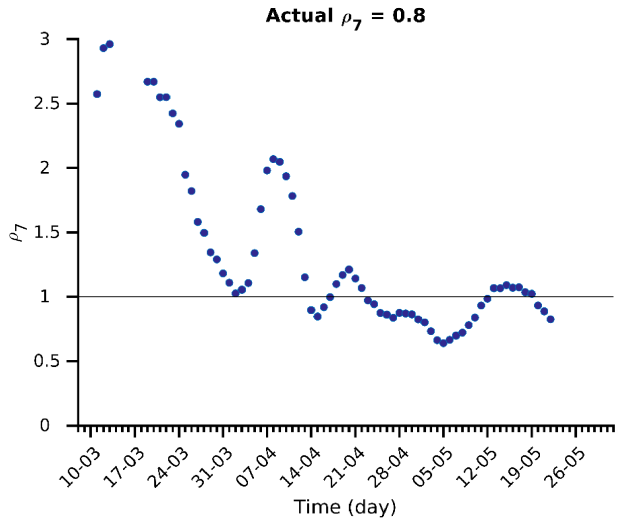


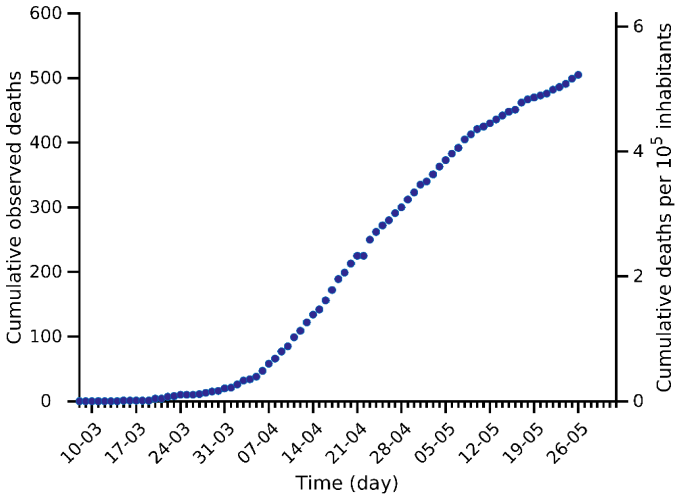



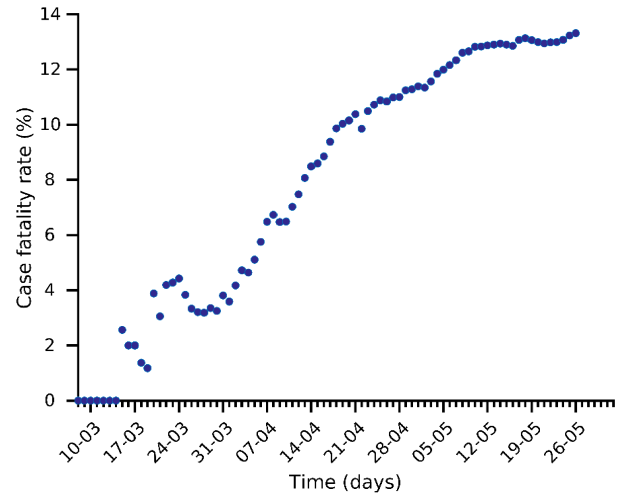



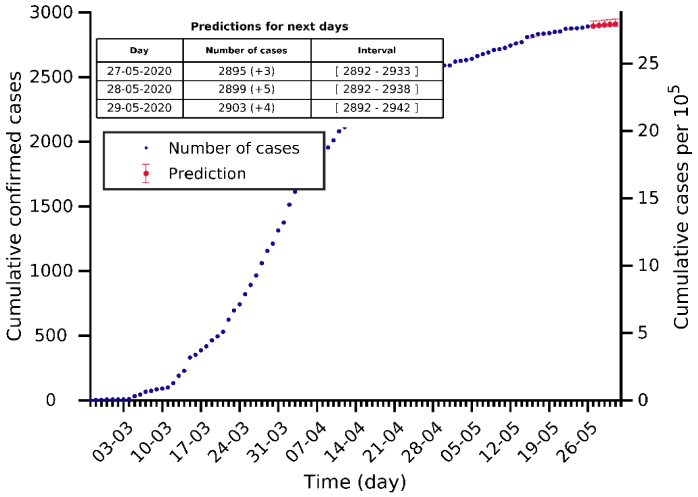



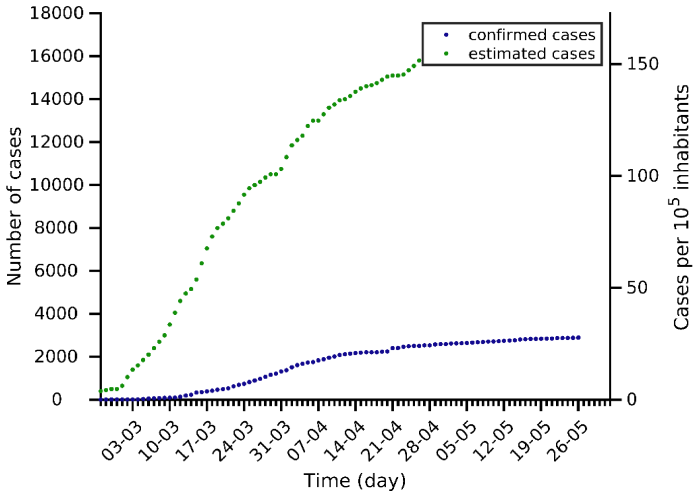



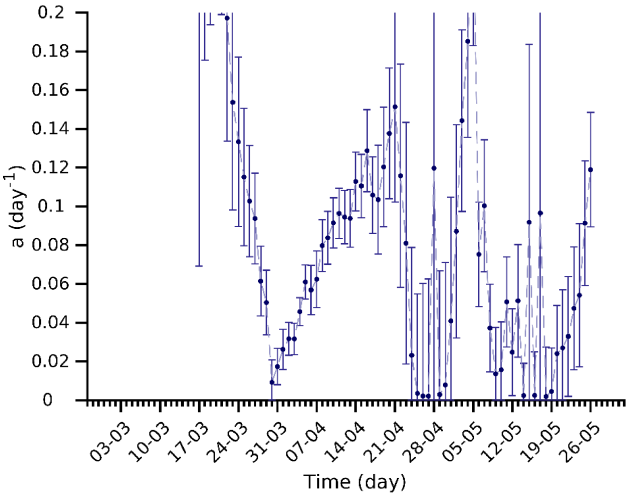



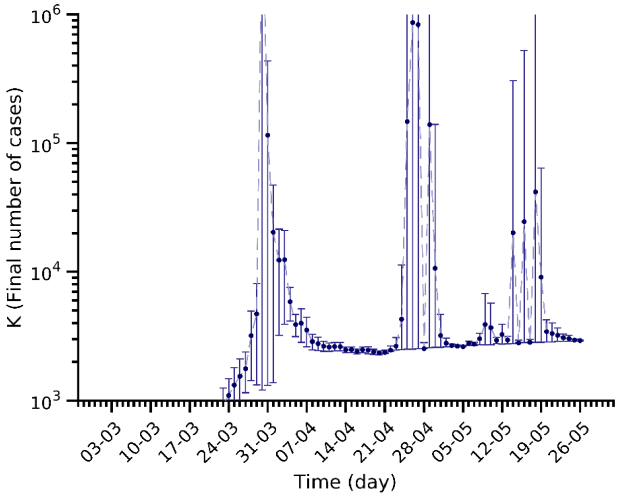



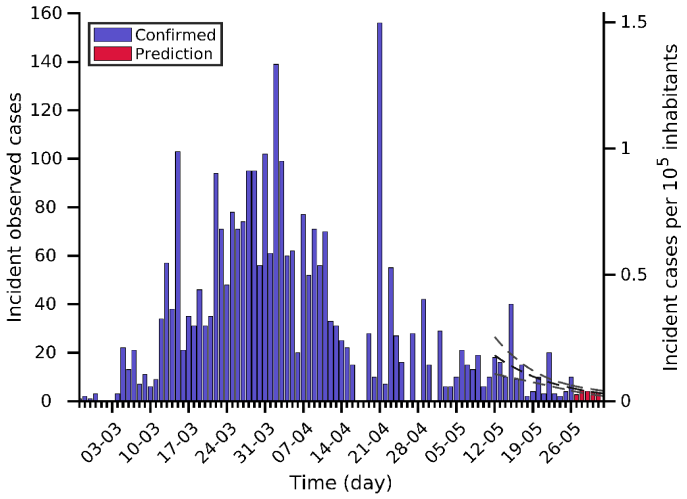
# Greece 26-05-2020. Population: 10.4M. Current cumulated incidence: $28/10^5$

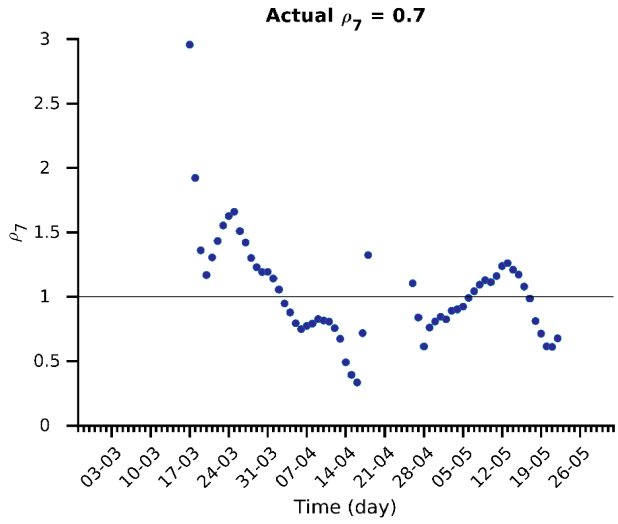


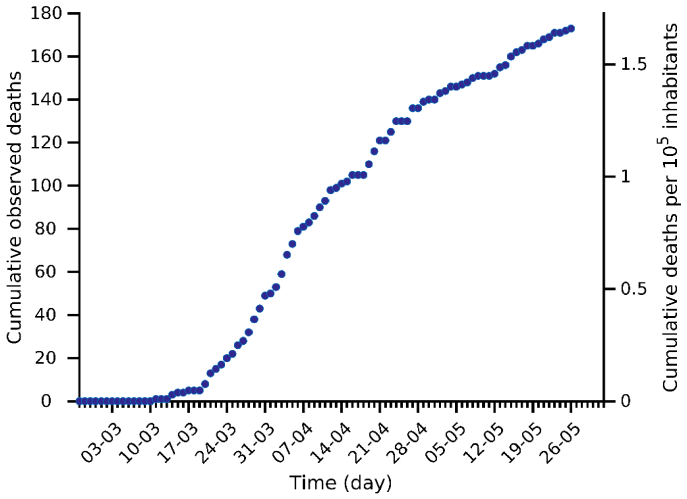



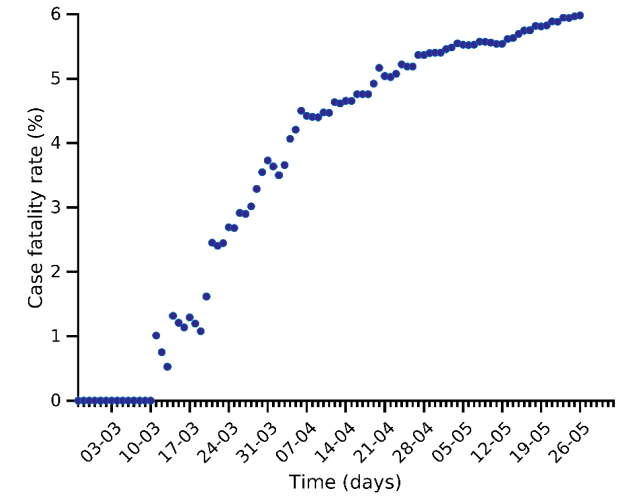



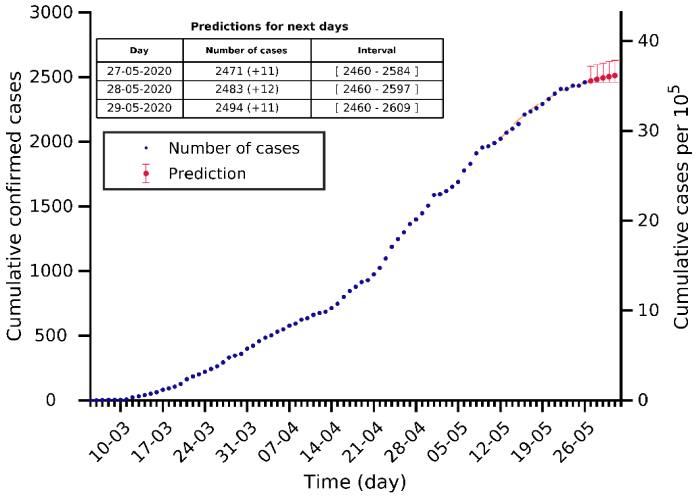



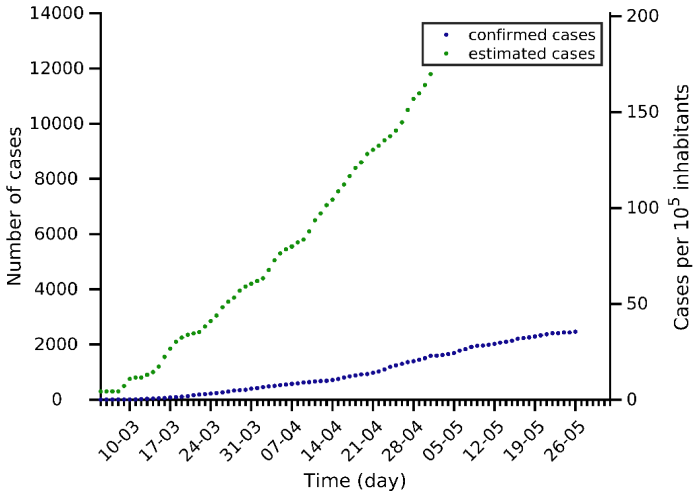



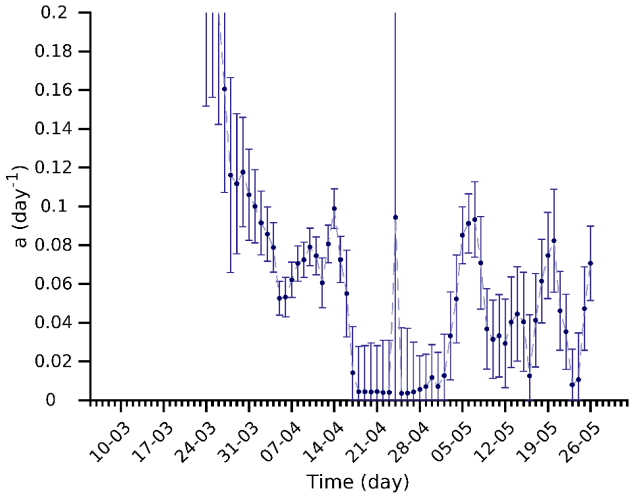



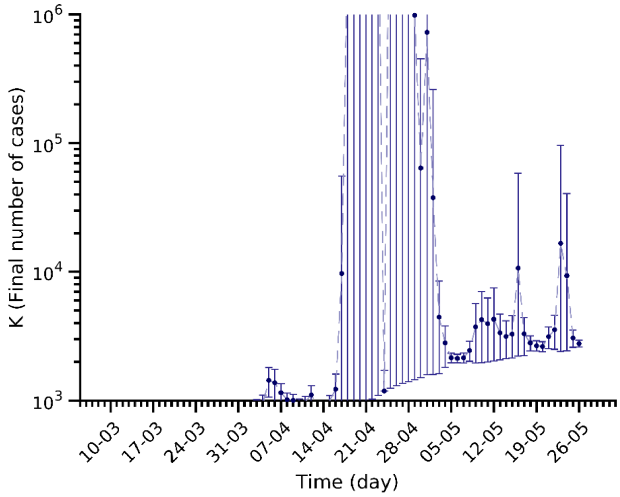



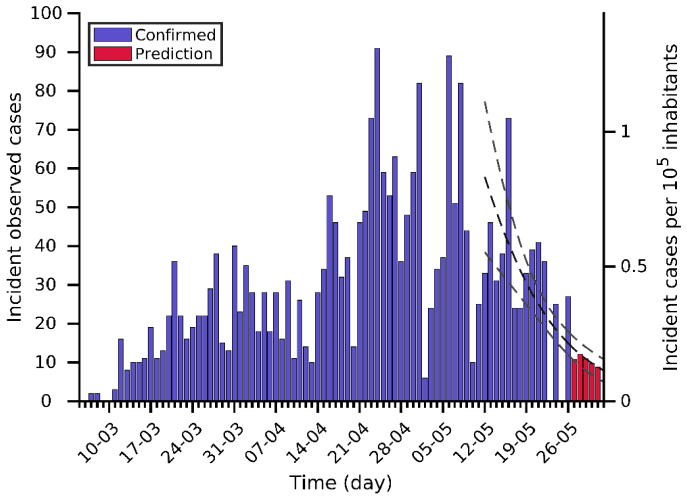
# Bulgaria 26-05-2020. Population: 6.9M. Current cumulated incidence: $35/10^5$

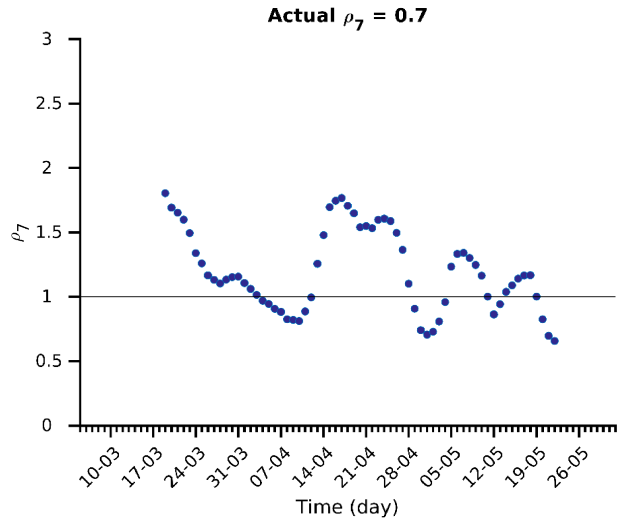


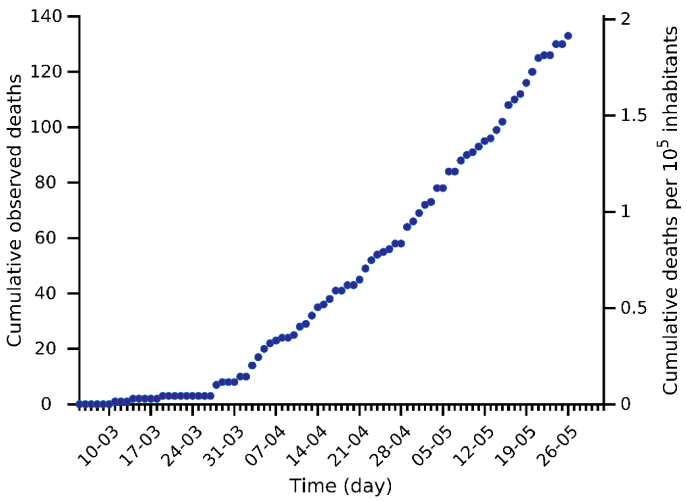



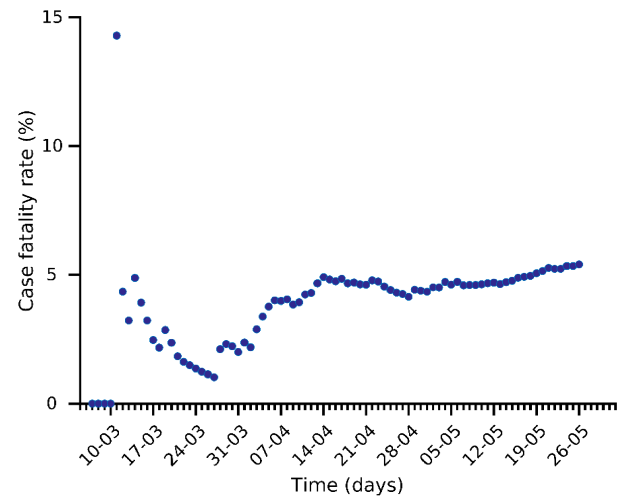



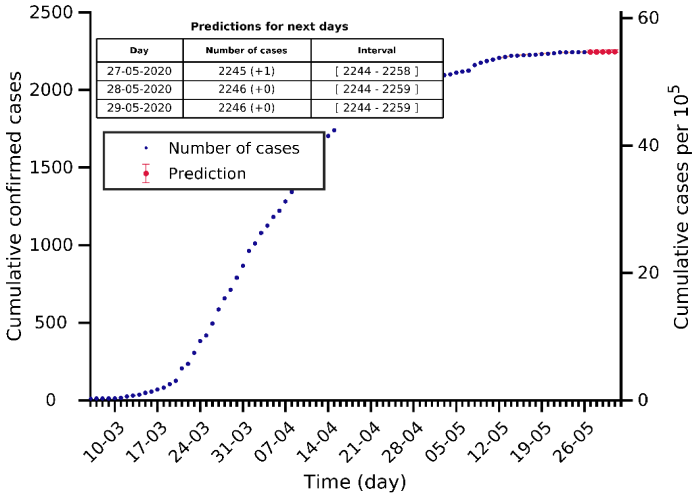



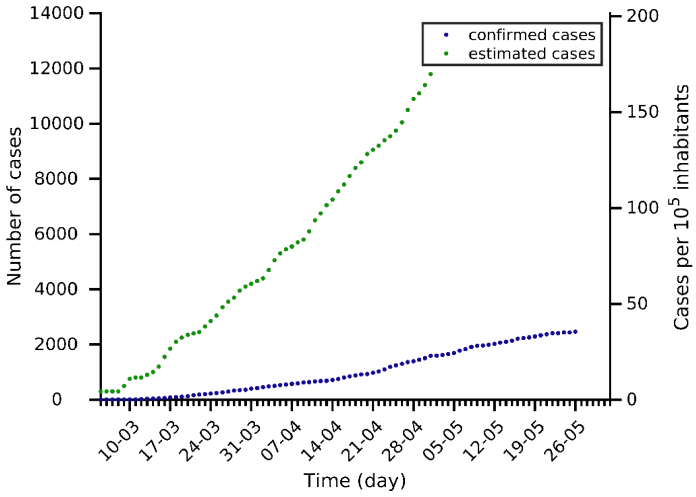



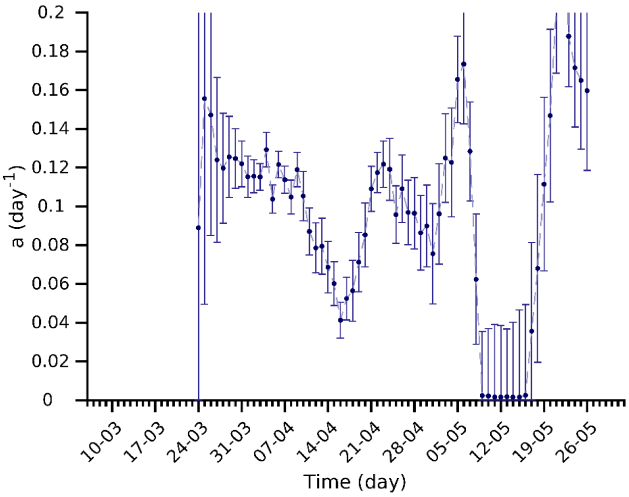



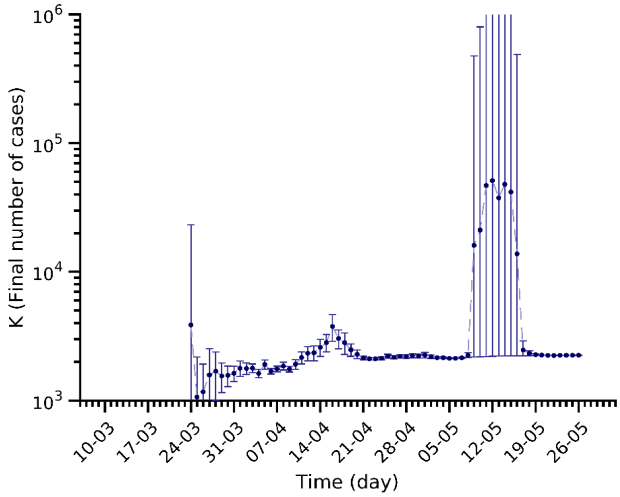



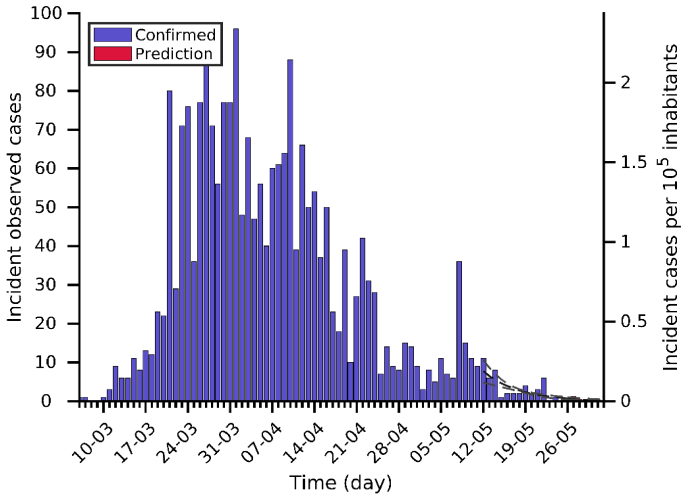
# Croatia 26-05-2020. Population: 4.1M. Current cumulated incidence: $55/10^5$

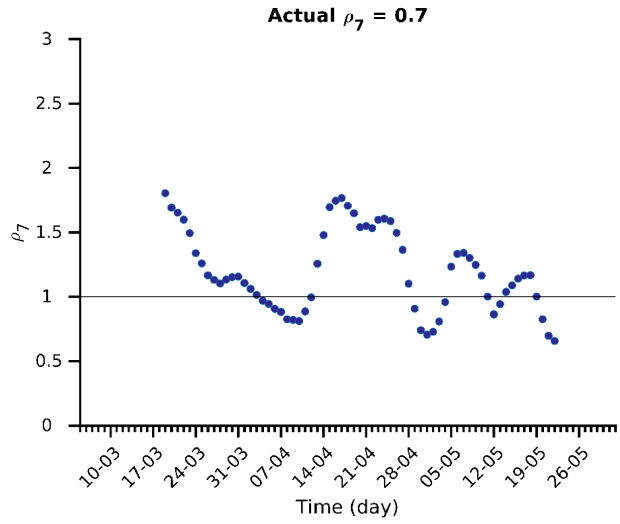


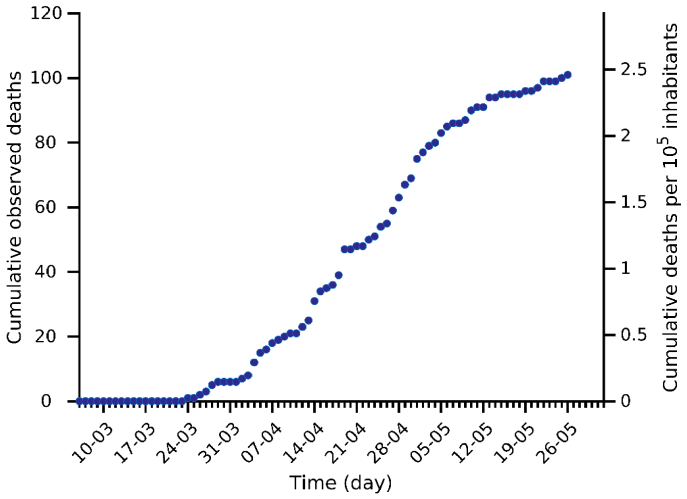



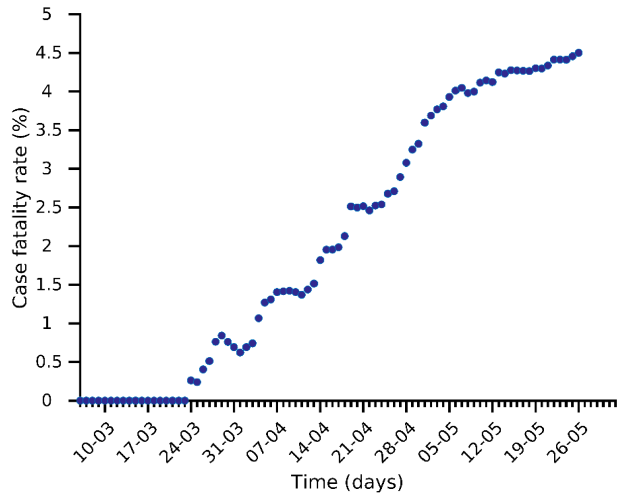



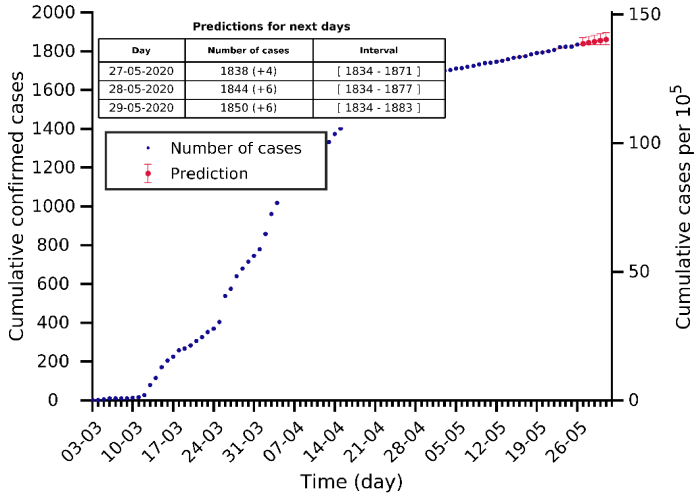



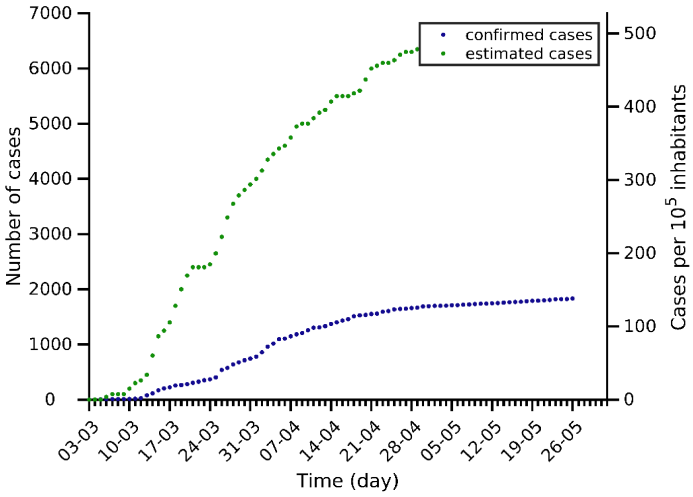



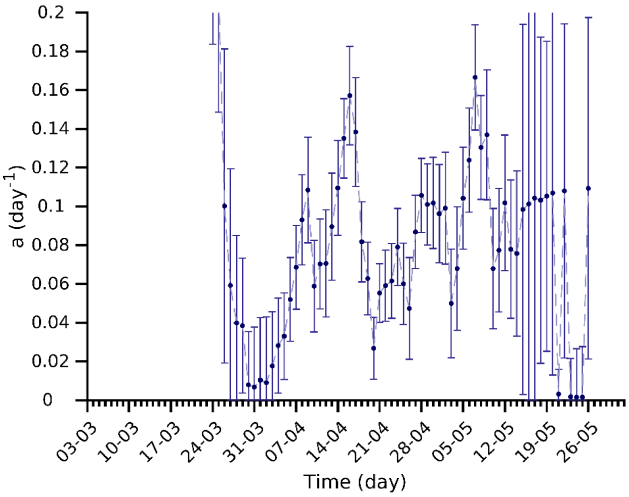



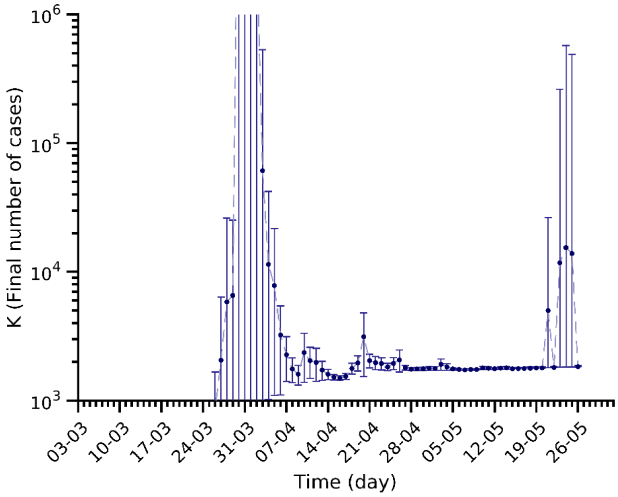



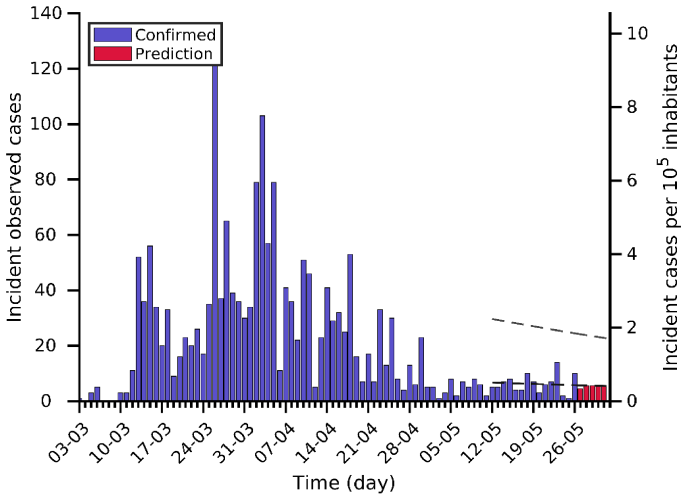
# Estonia 26-05-2020. Population: 1.3M. Current cumulated incidence: 138/$10^5$

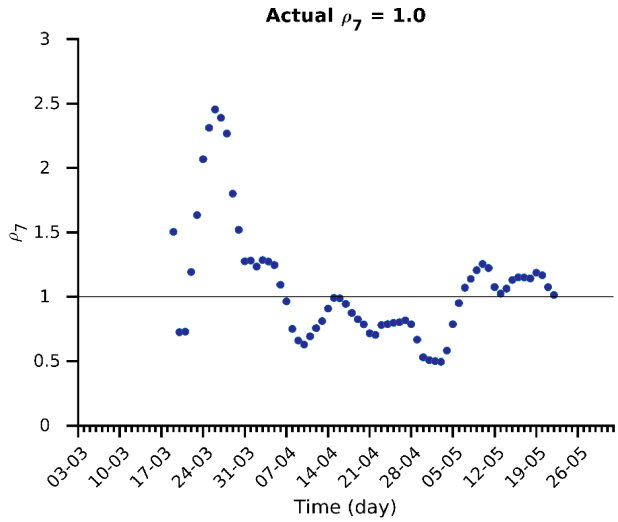


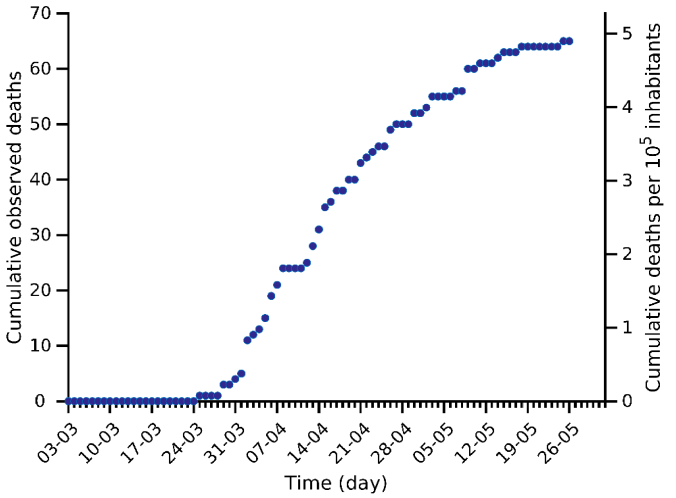



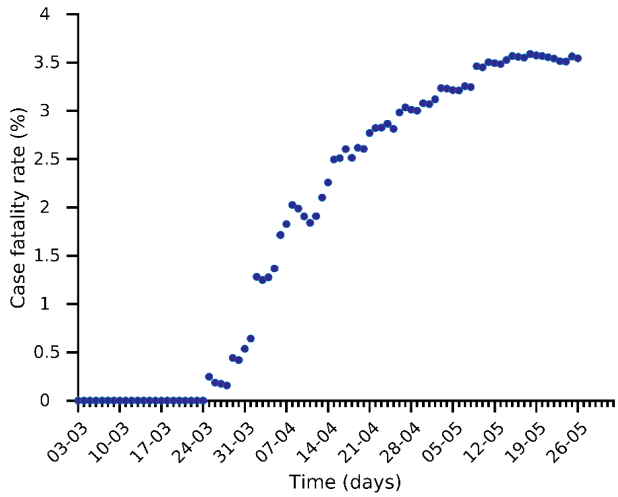



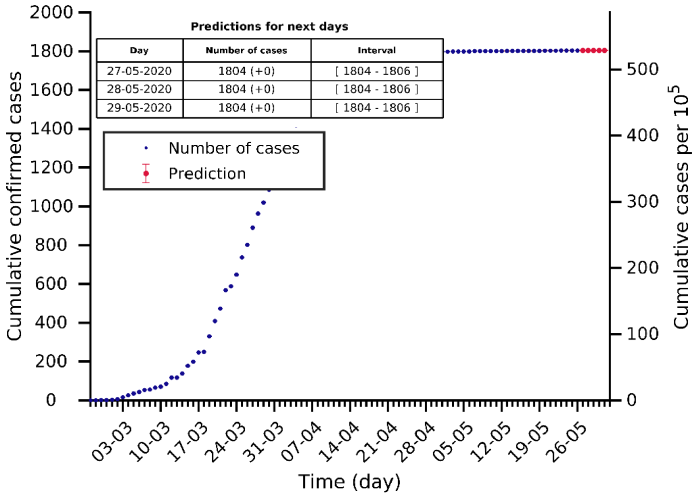



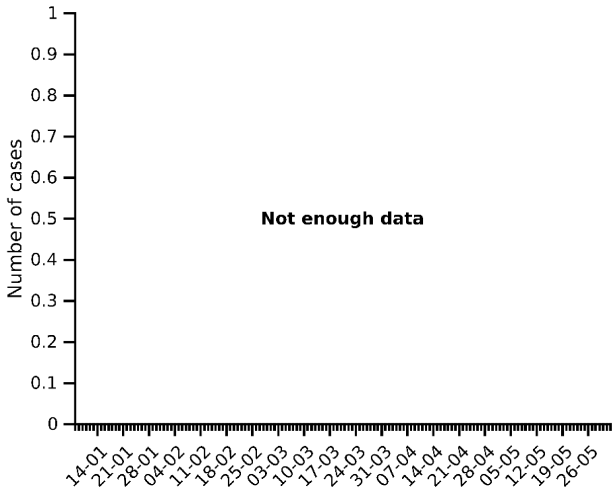



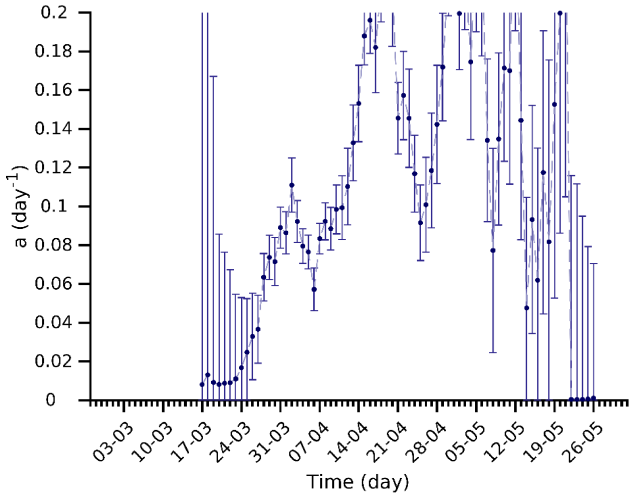



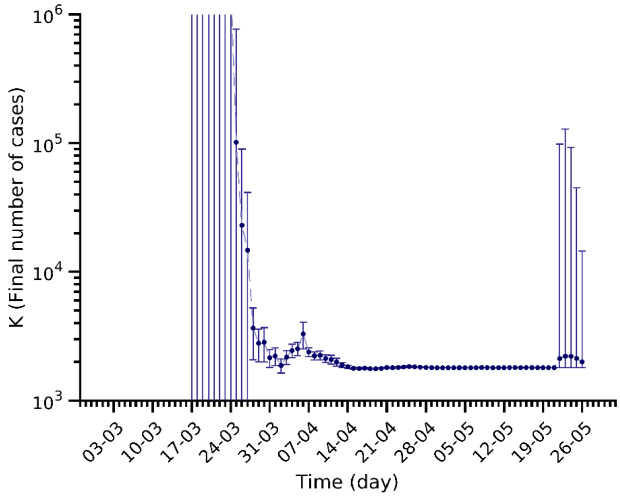



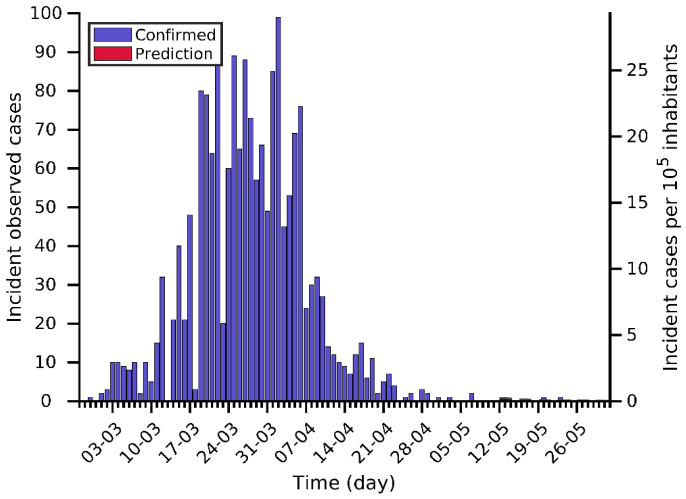
# Iceland 26-05-2020. Population: 0.3M. Current cumulated incidence: 529/$10^5$

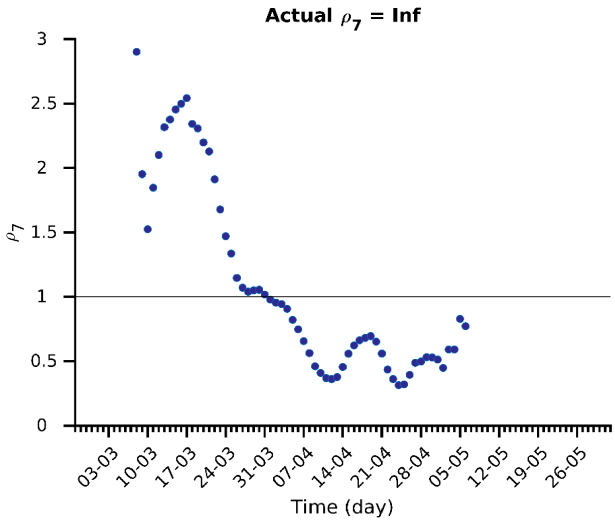


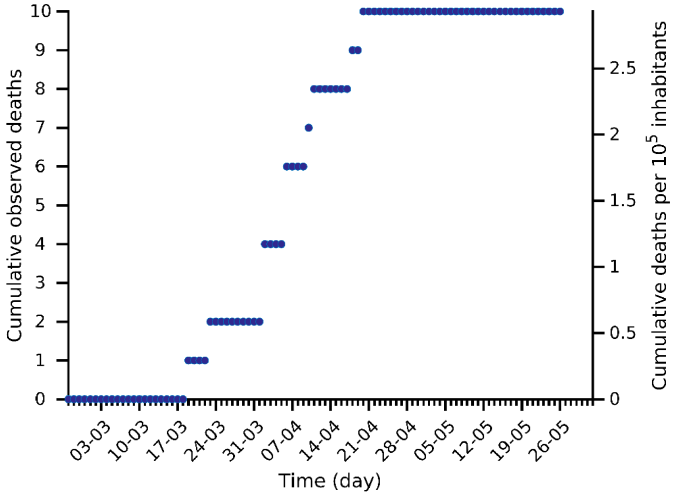



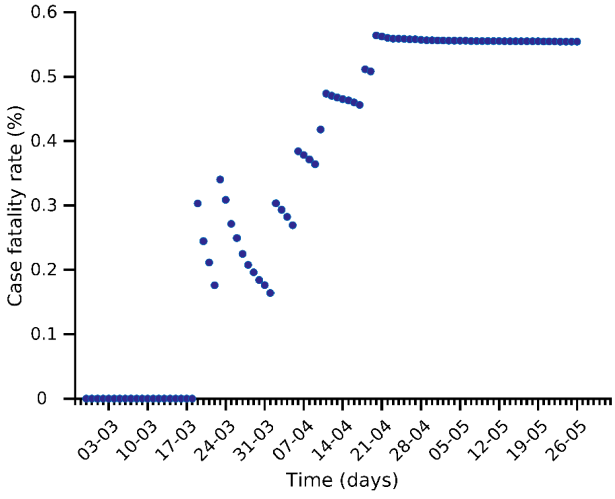



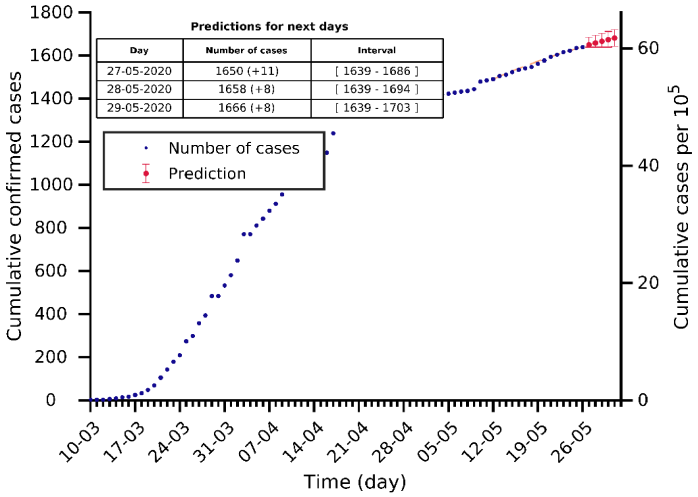



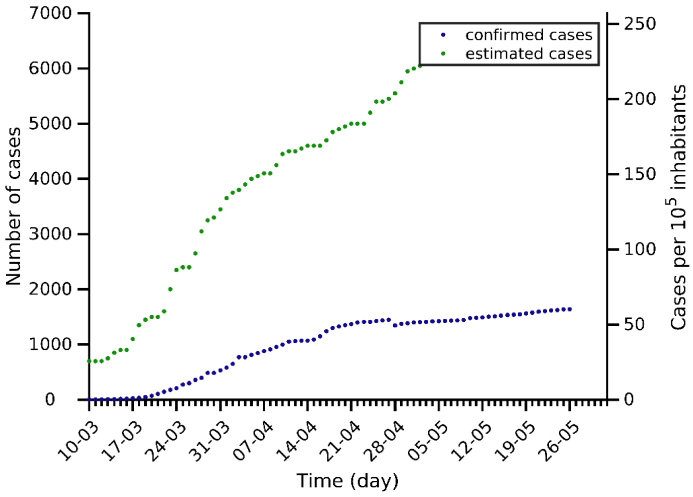



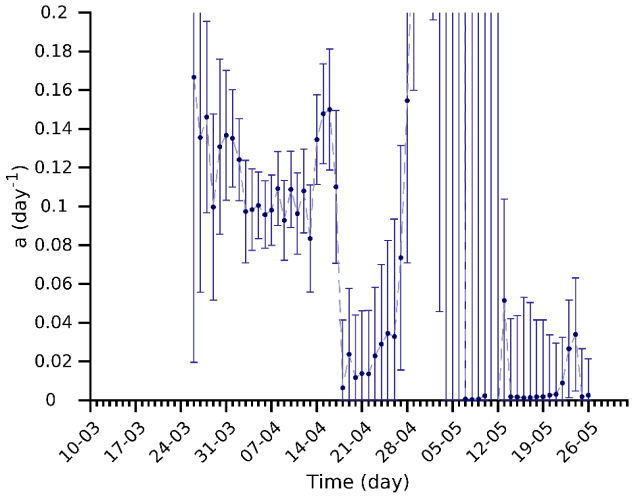



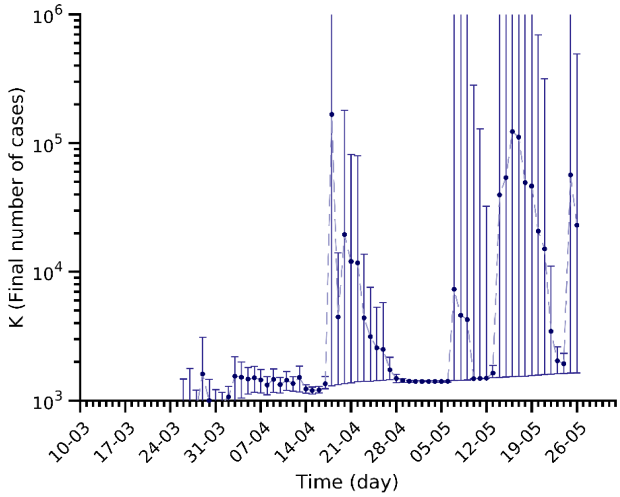



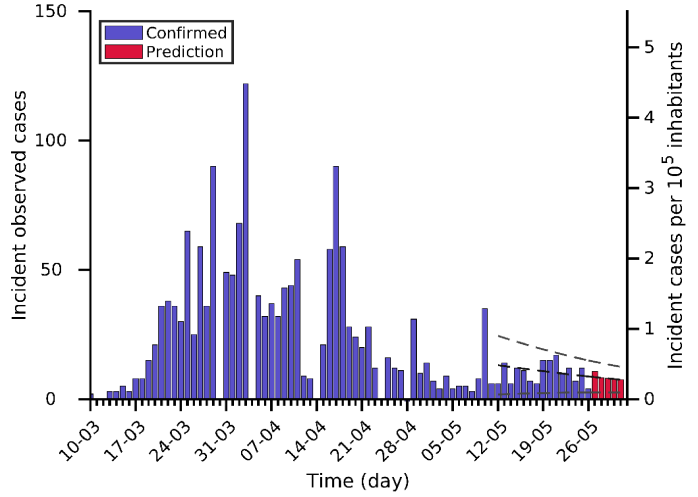
# Lithuania 26-05-2020. Population: 2.7M. Current cumulated incidence: $60/10^5$

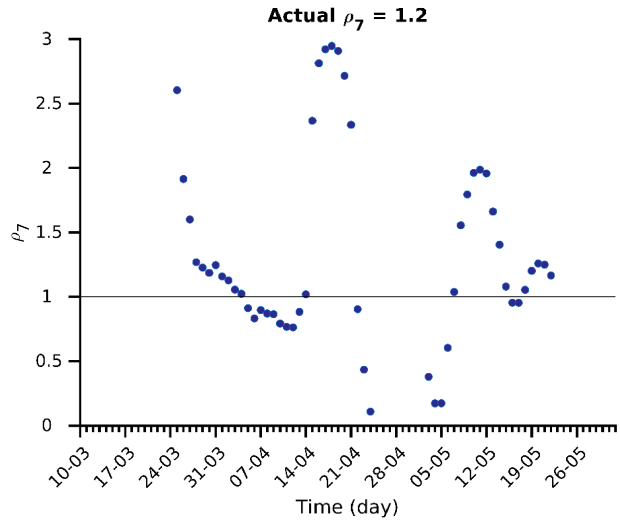


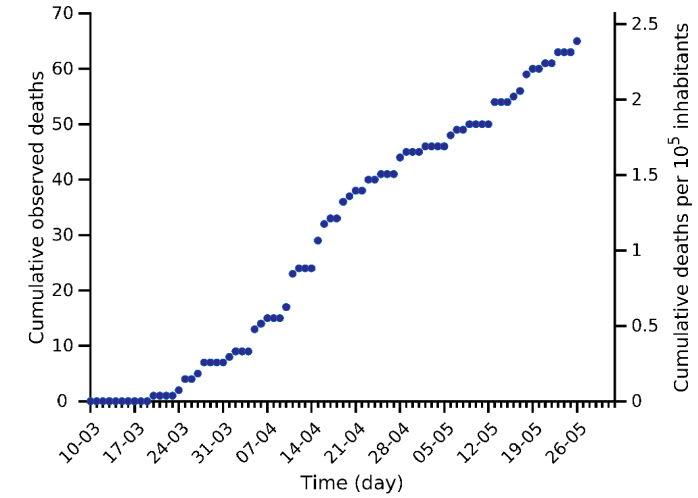



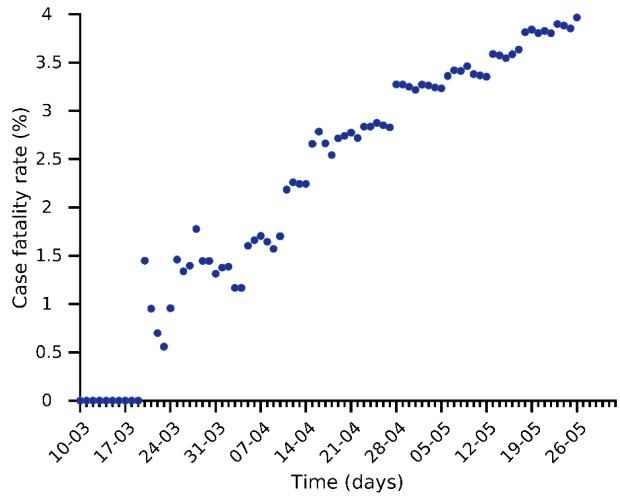



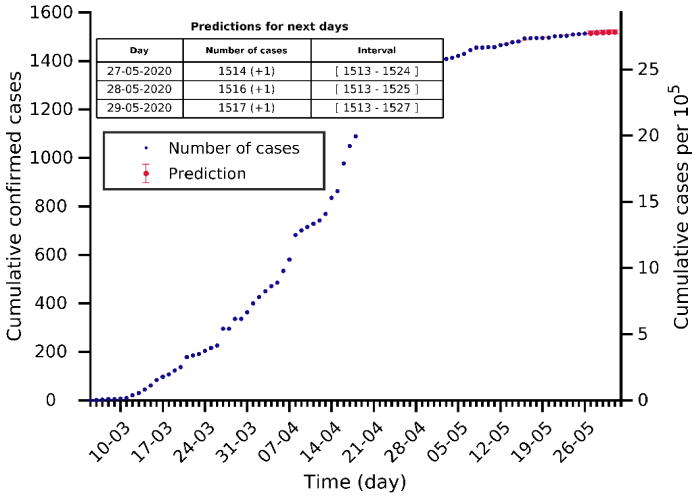



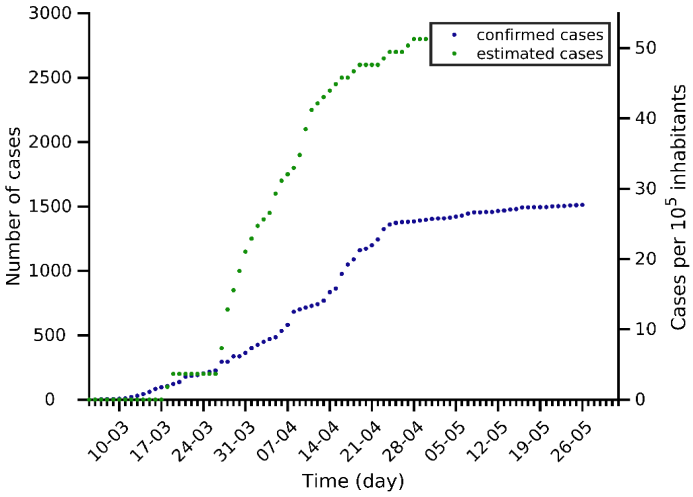



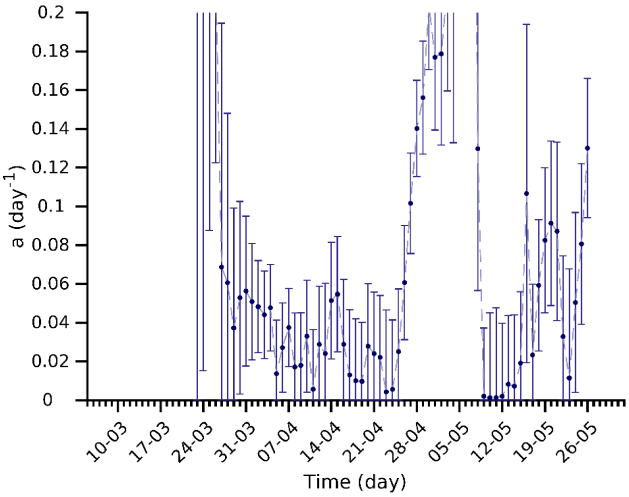



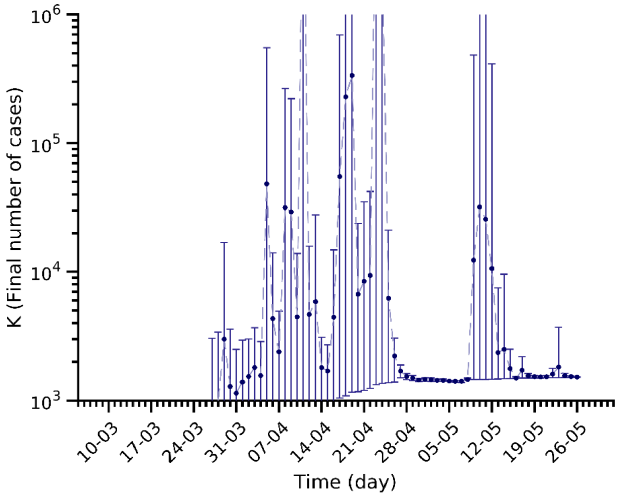



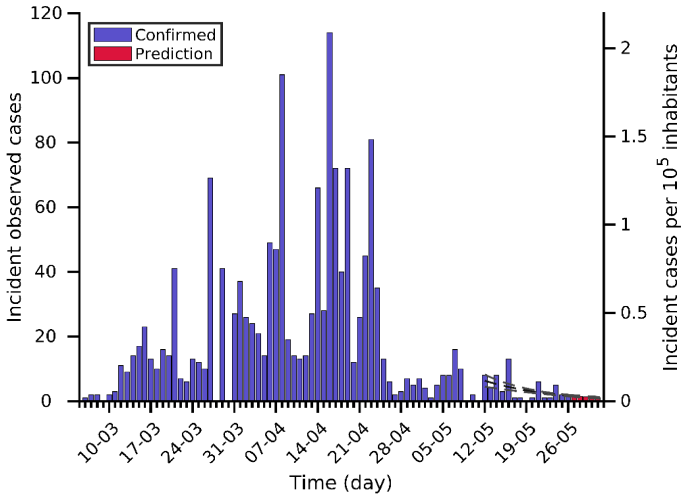
# Slovakia 26-05-2020. Population: 5.5M. Current cumulated incidence: 28/$10^5$

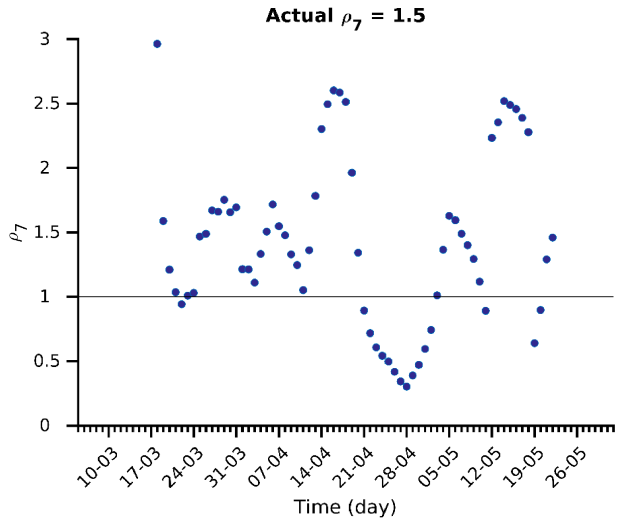


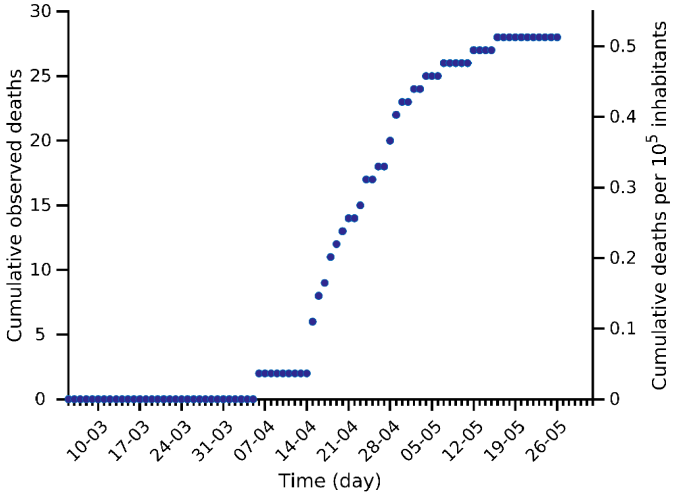



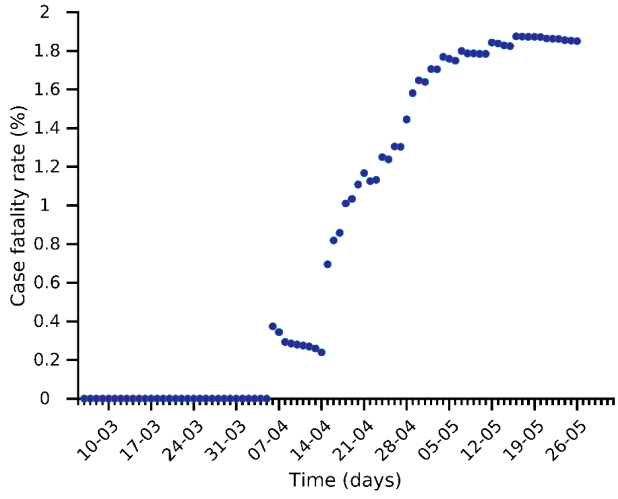



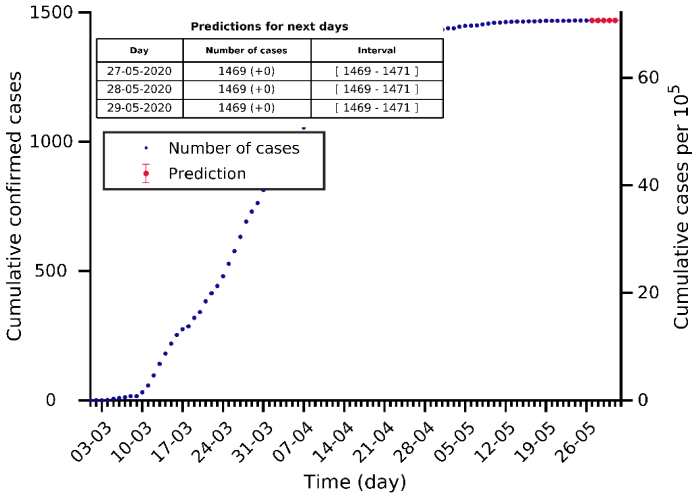



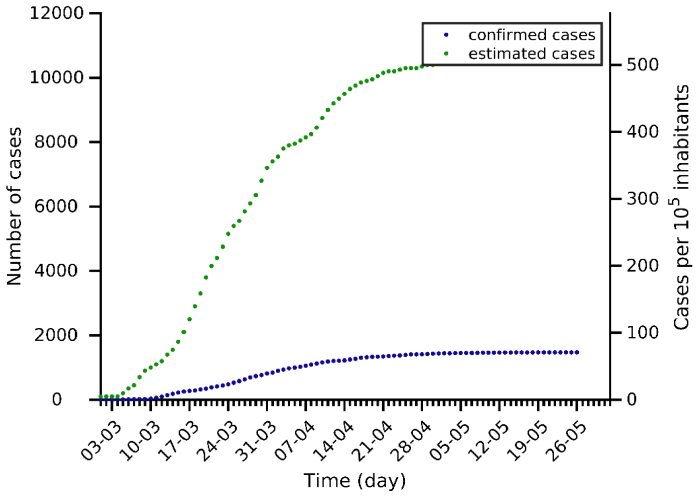



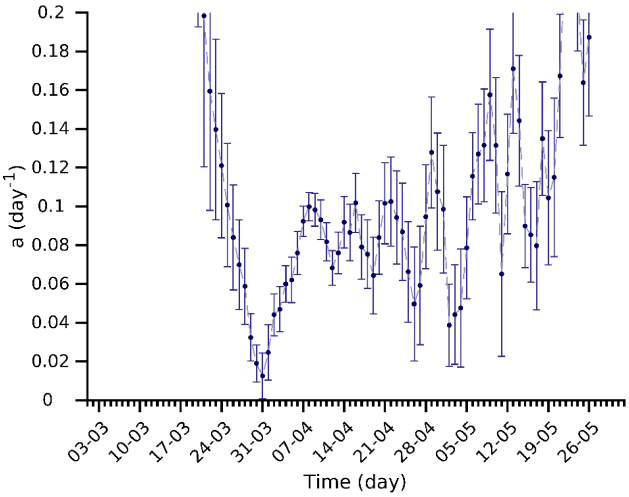



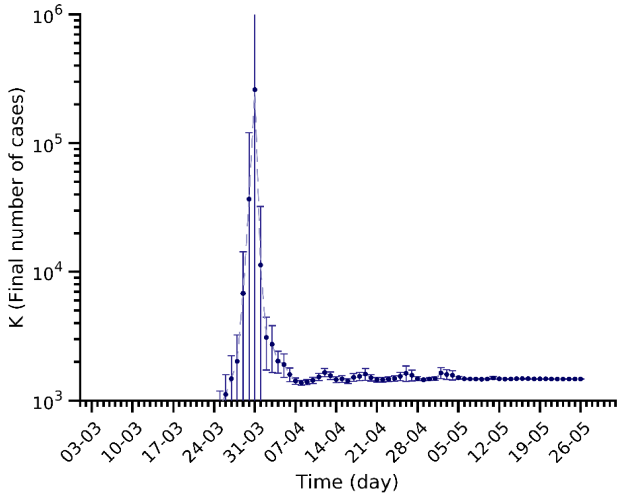



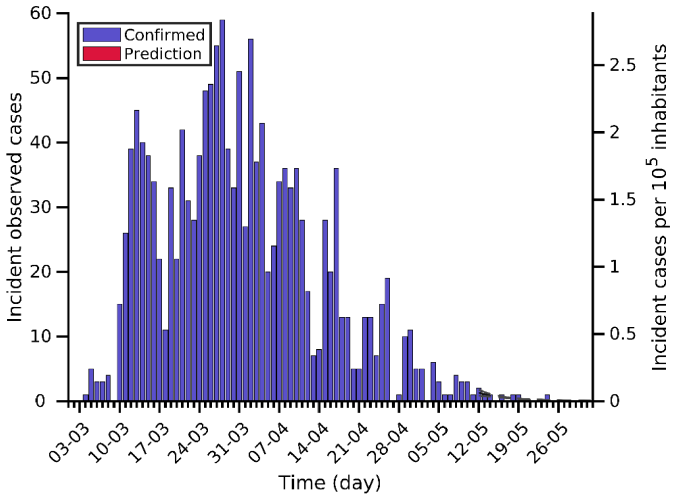
# Slovenia 26-05-2020. Population: 2.1M. Current cumulated incidence: 71/$10^5$

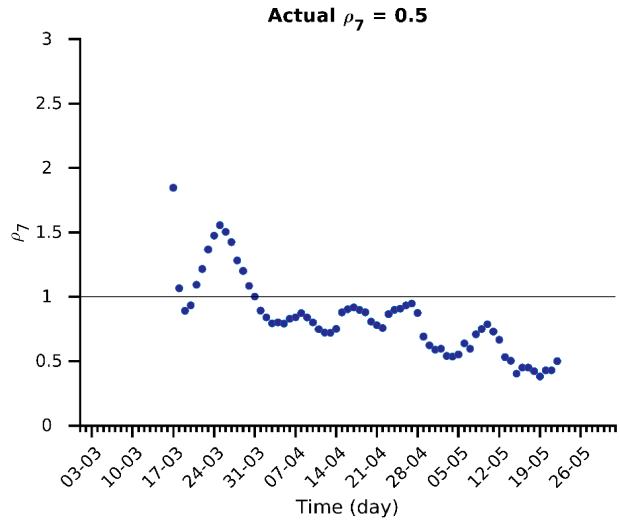


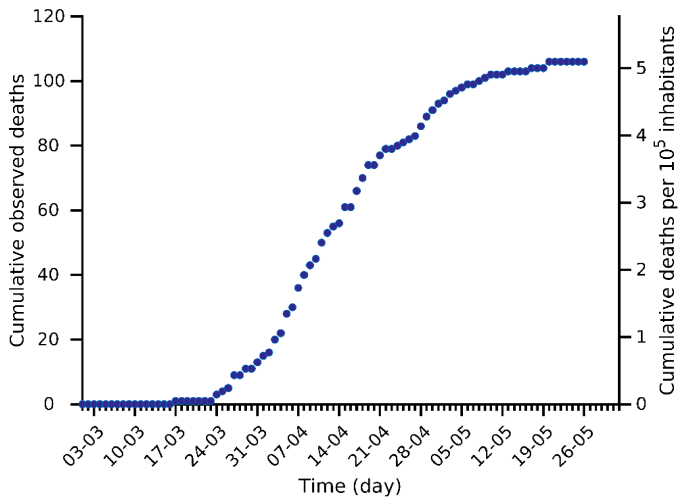



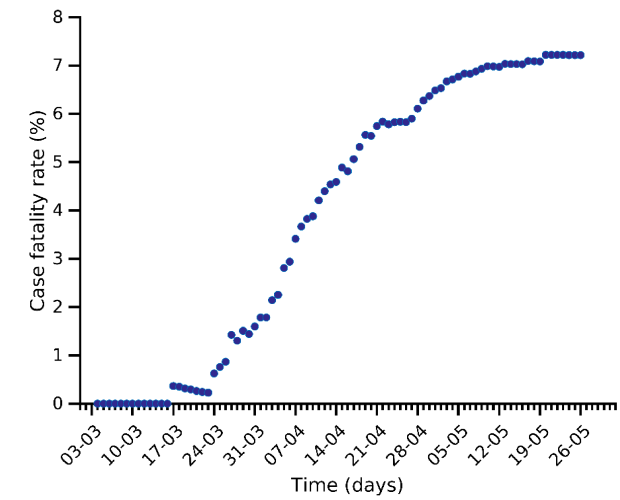



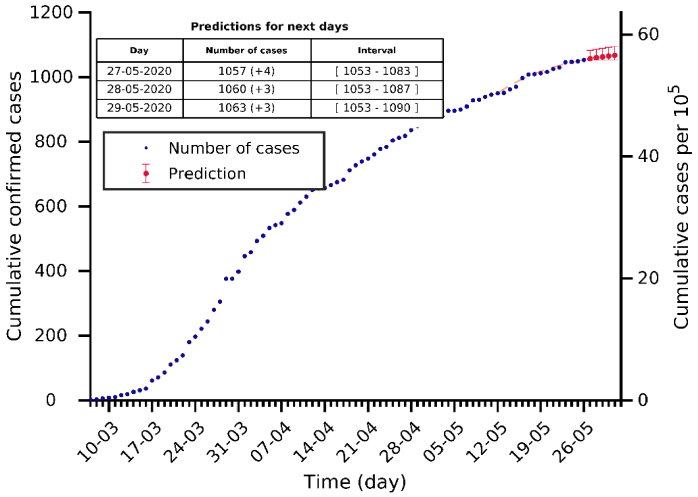



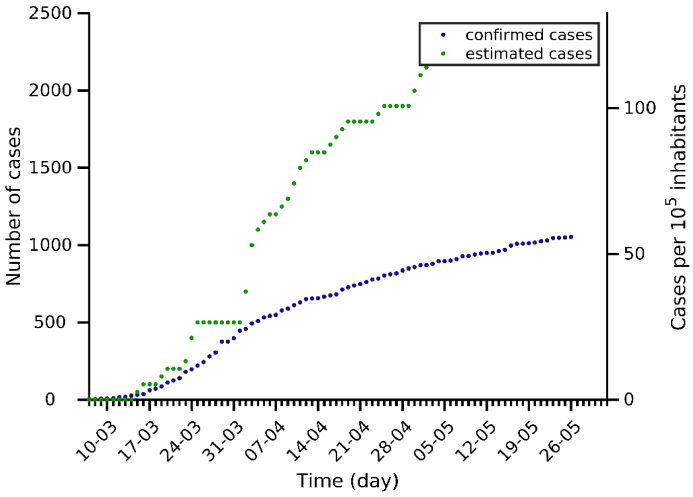



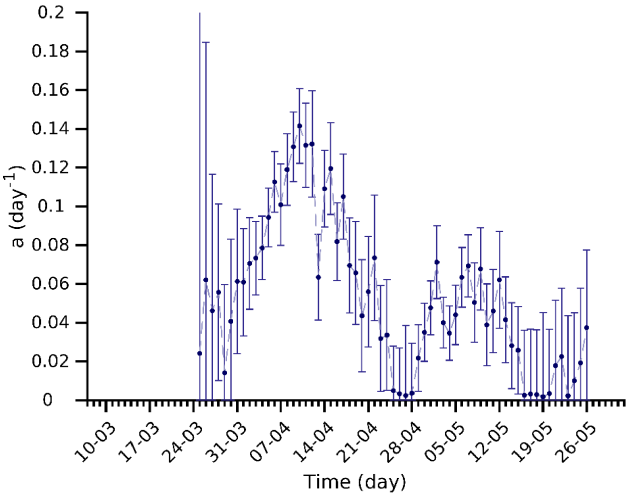



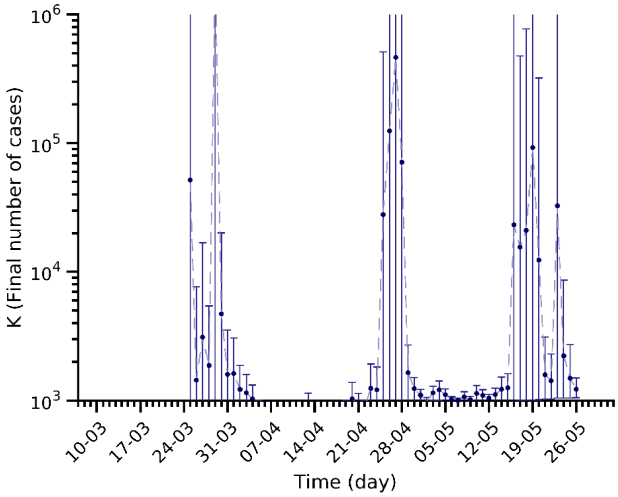



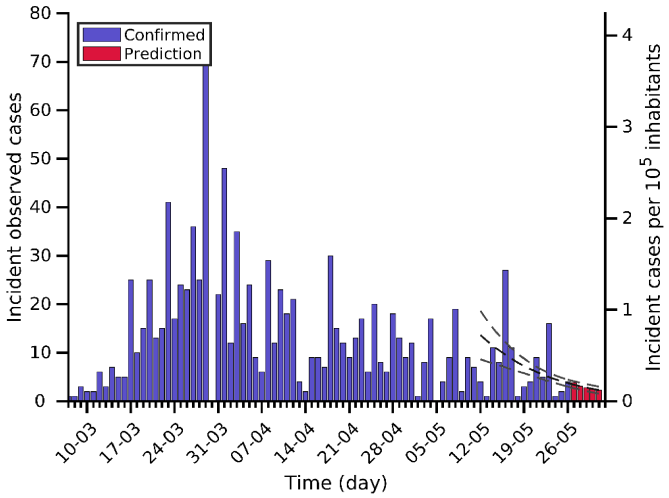
# Latvia 26-05-2020. Population: 1.9M. Current cumulated incidence: 56/$10^5$

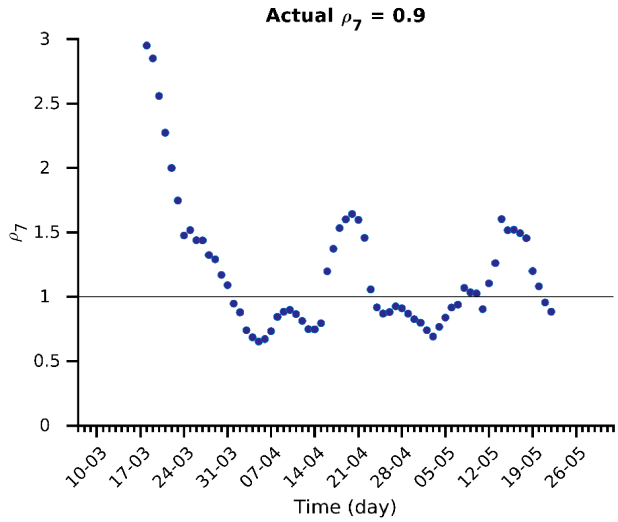


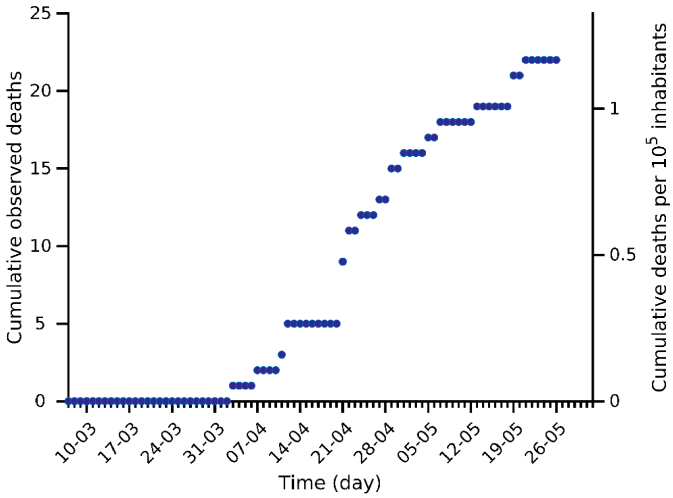



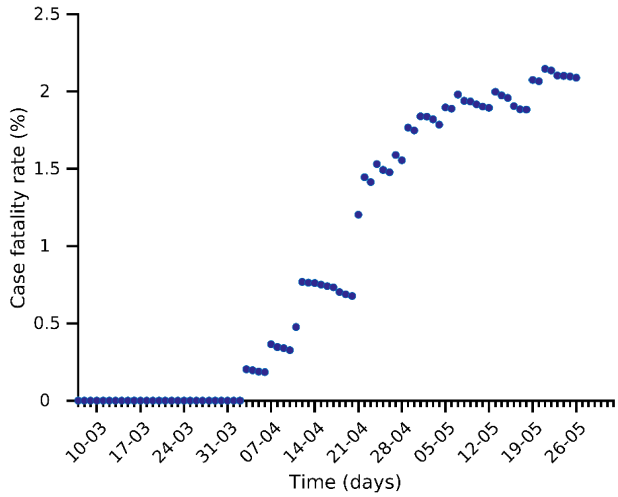



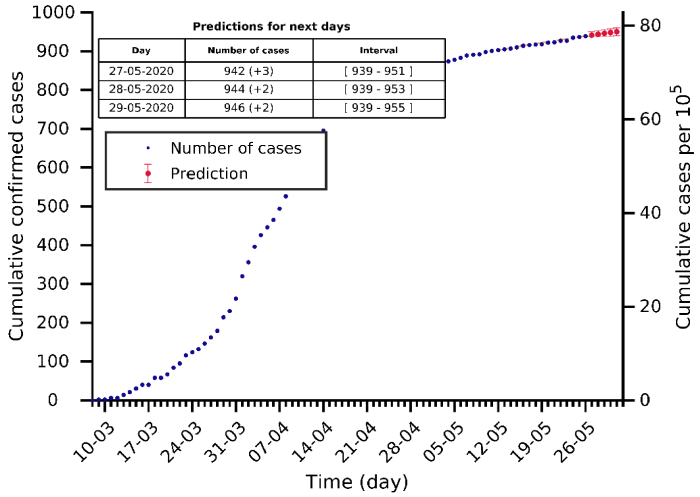



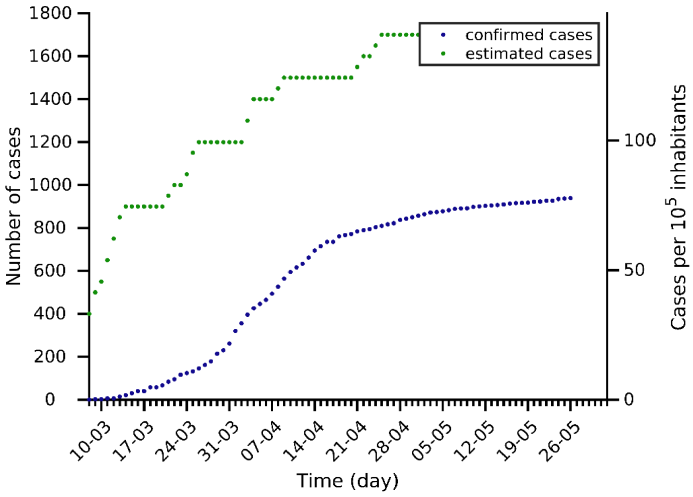



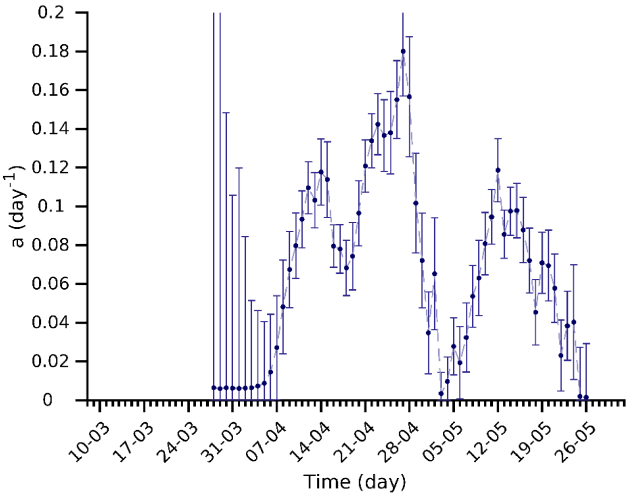



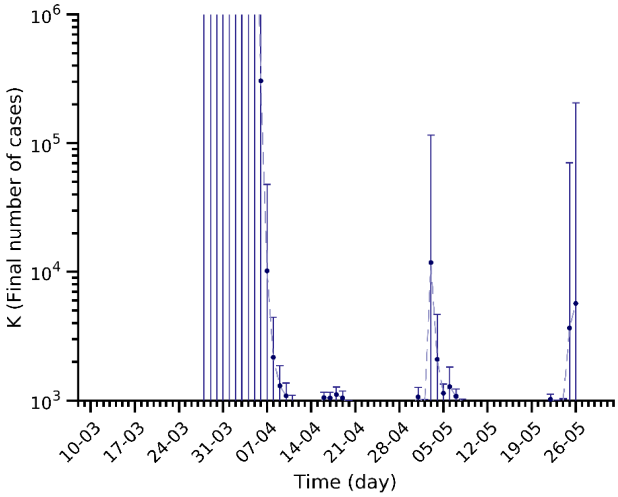



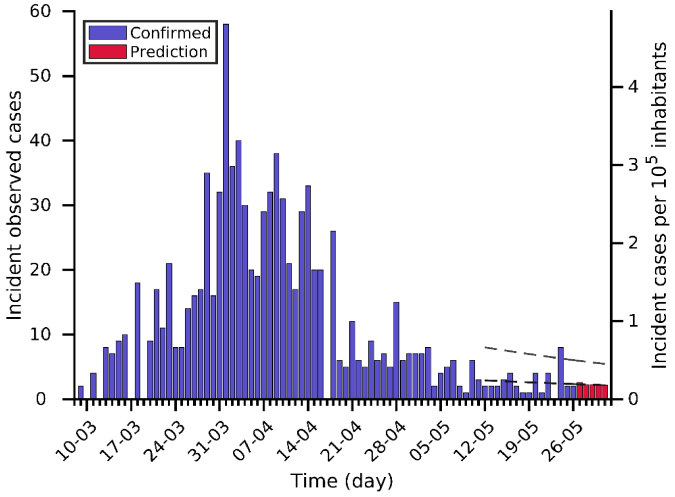
# Cyprus 26-05-2020. Population: 1.2M. Current cumulated incidence: $78/10^5$

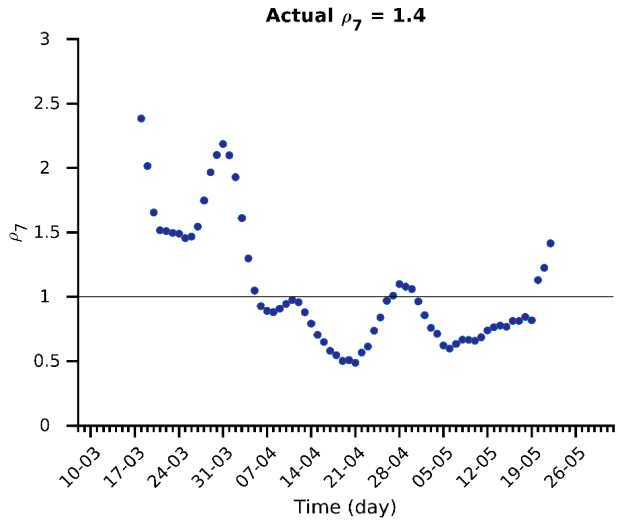


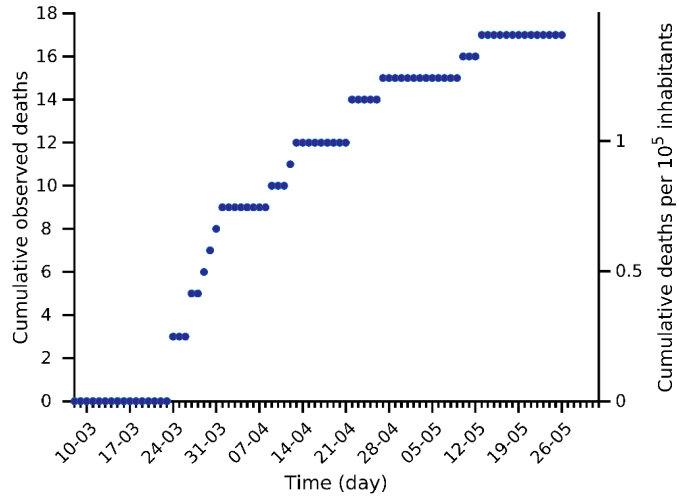



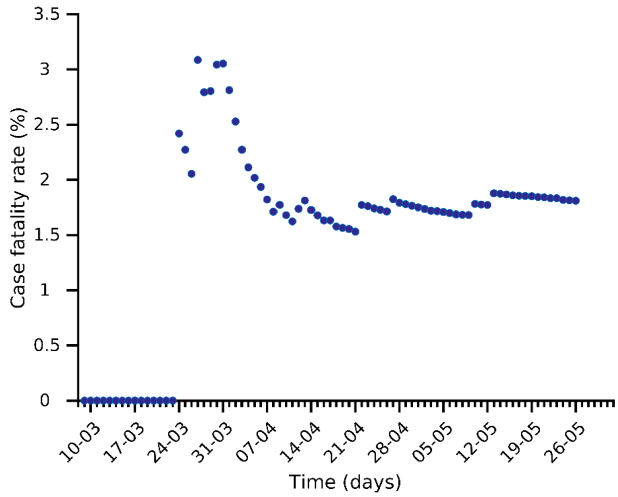



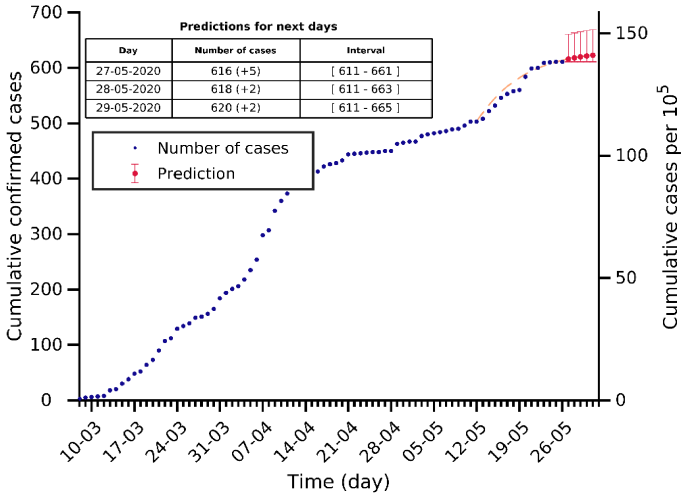



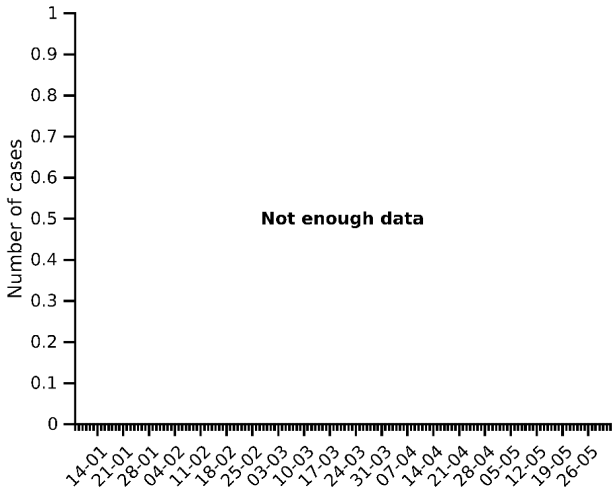



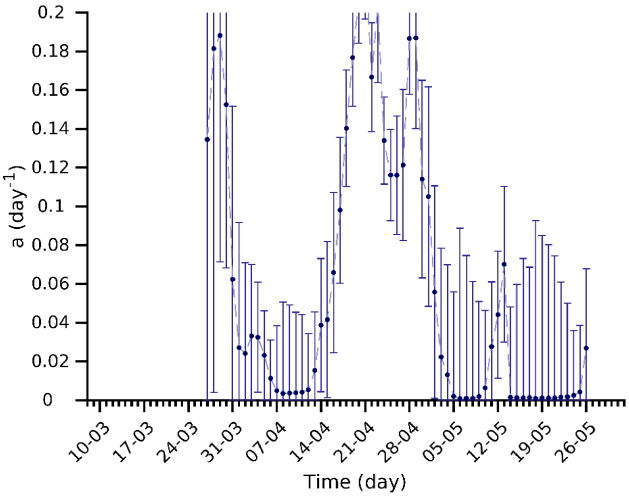



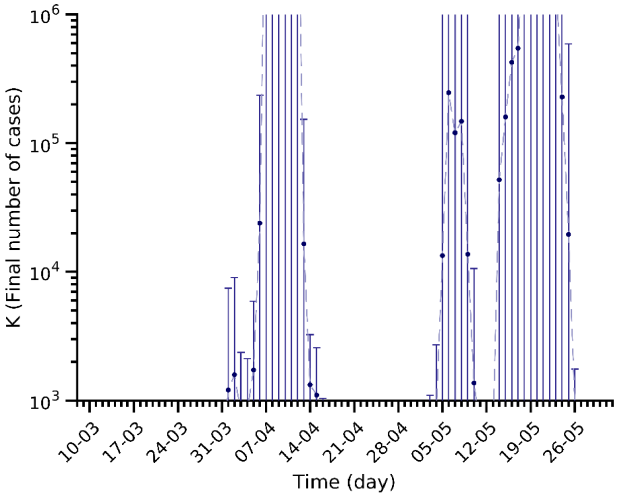



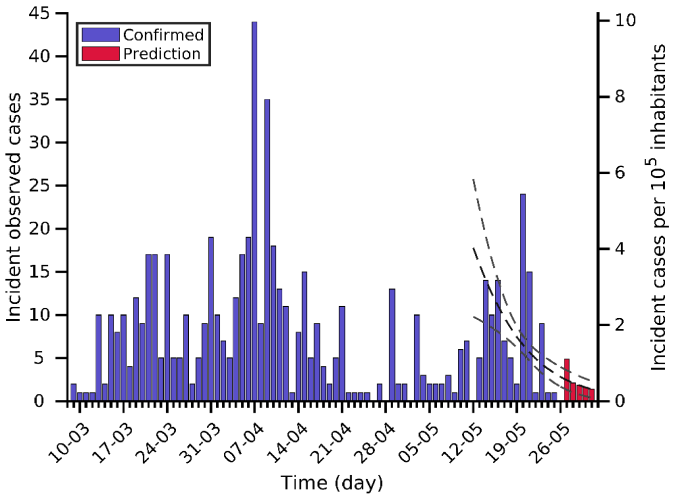
# Malta 26-05-2020. Population: 0.4M. Current cumulated incidence: 138/$10^5$

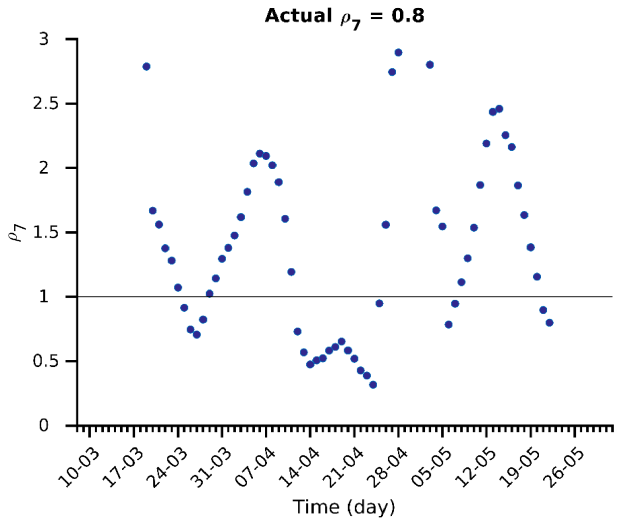


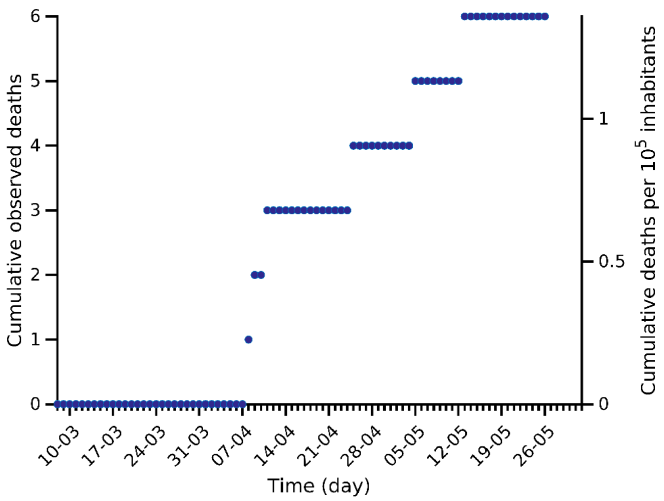



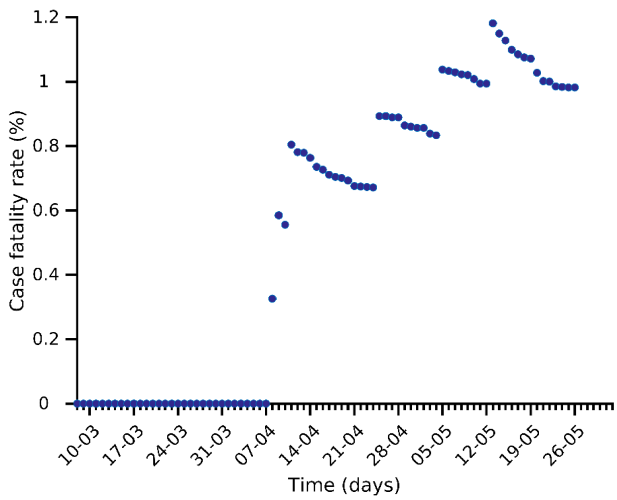



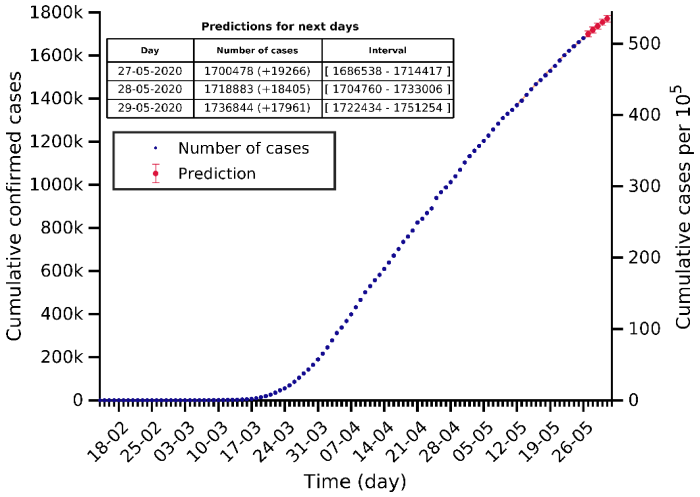



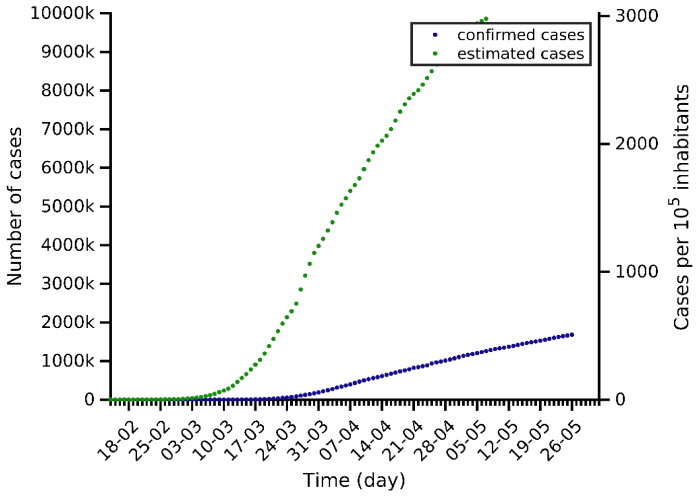



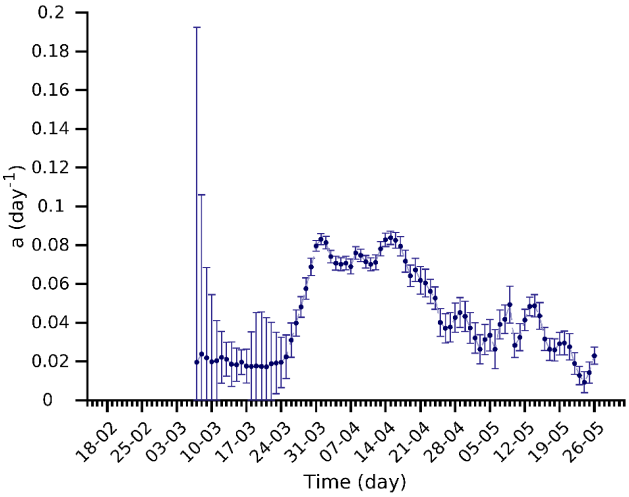
# (2) Analysis and prediction of COVID-19 for other countries

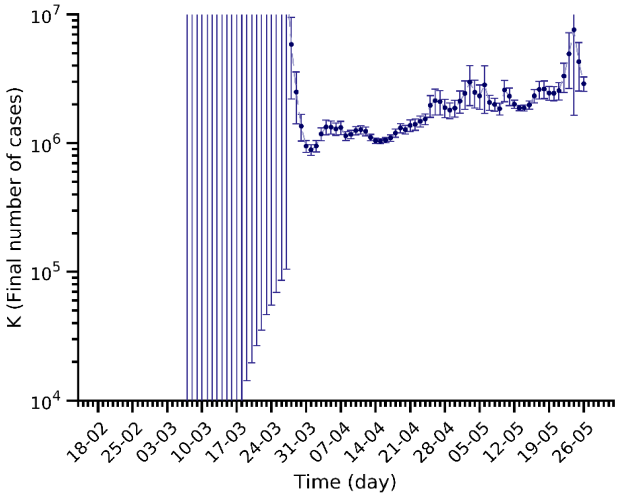
Data obtained from https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases

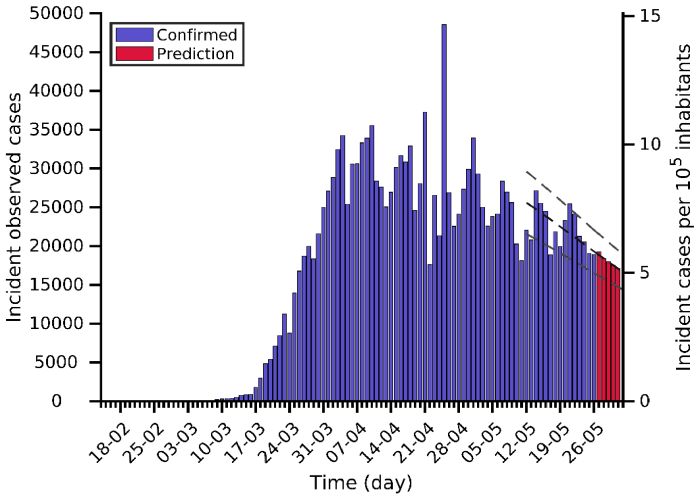
# USA 26-05-2020. Population: 331.0M. Current cumulated incidence: 508/10⁵

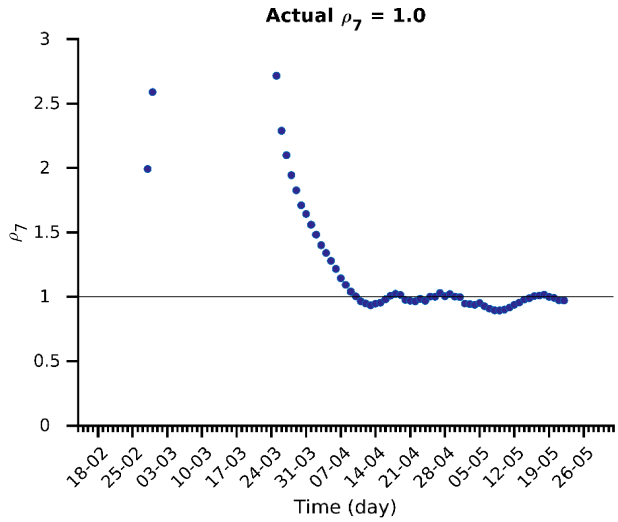


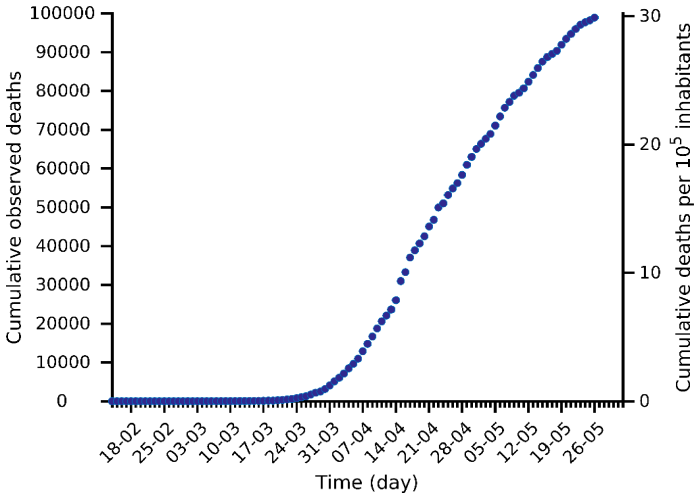



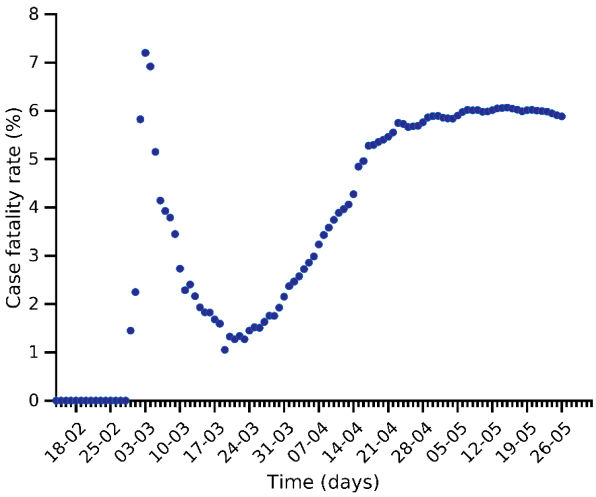



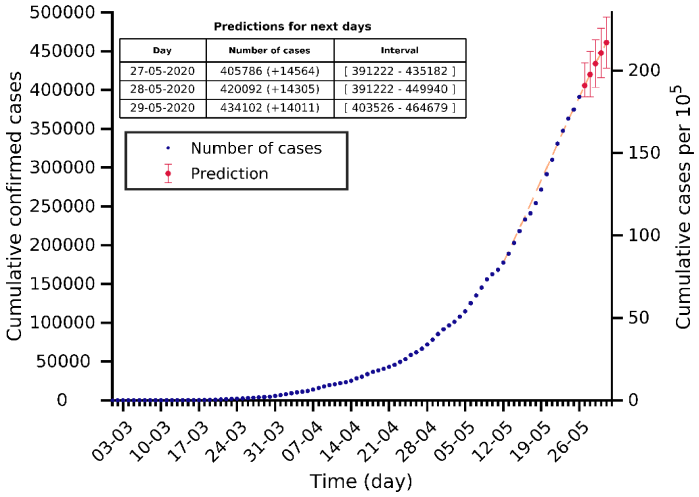



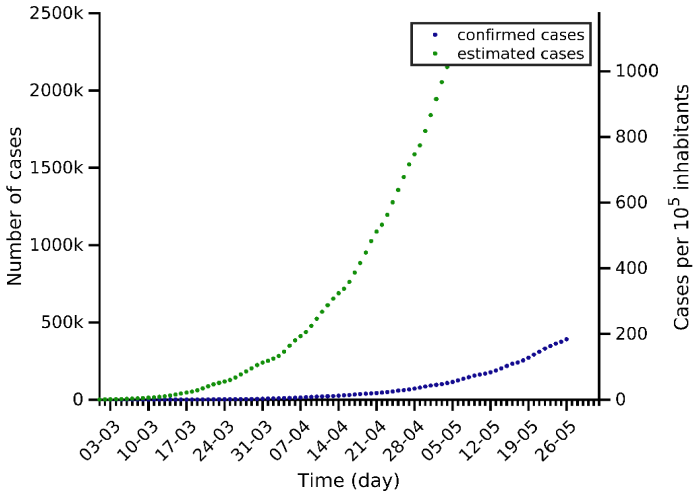



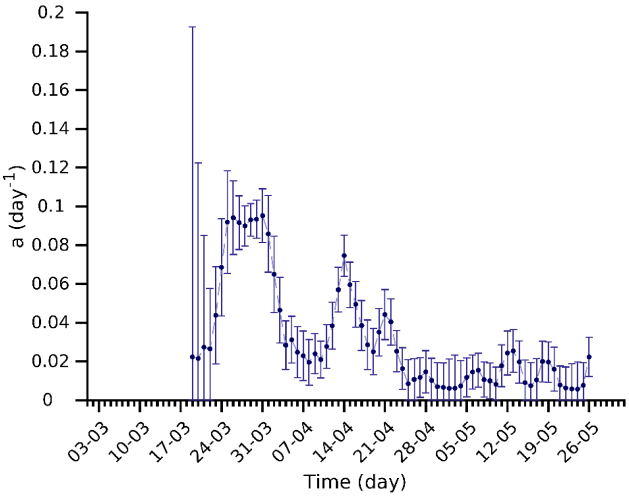



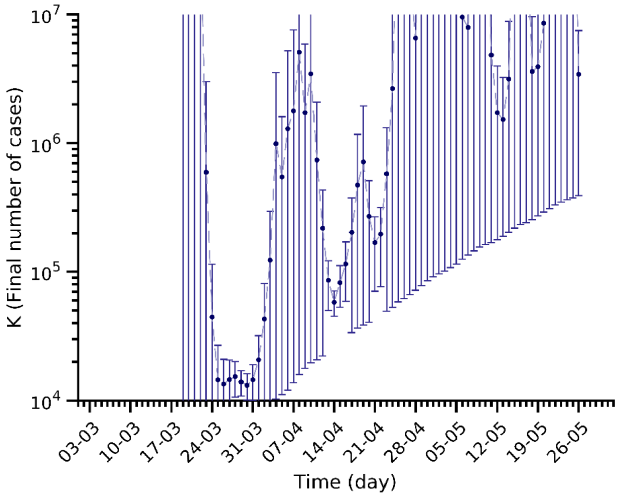



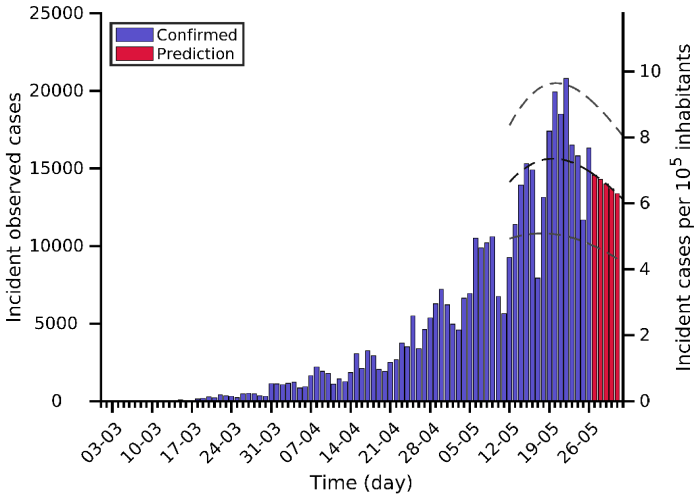
# Brazil 26-05-2020. Population: 212.6M. Current cumulated incidence: 184/$10^5$

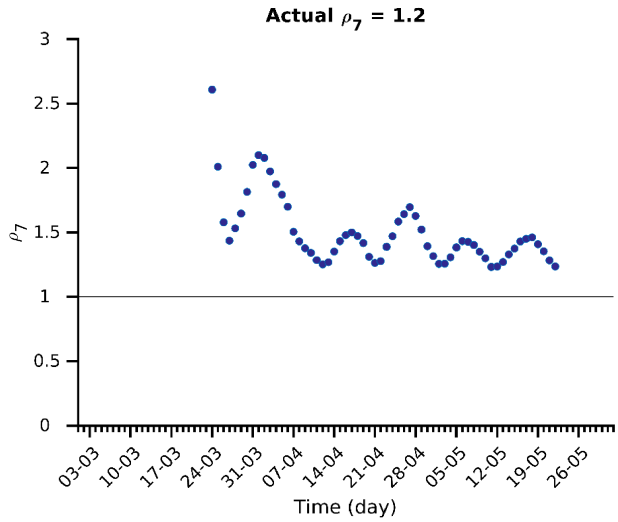


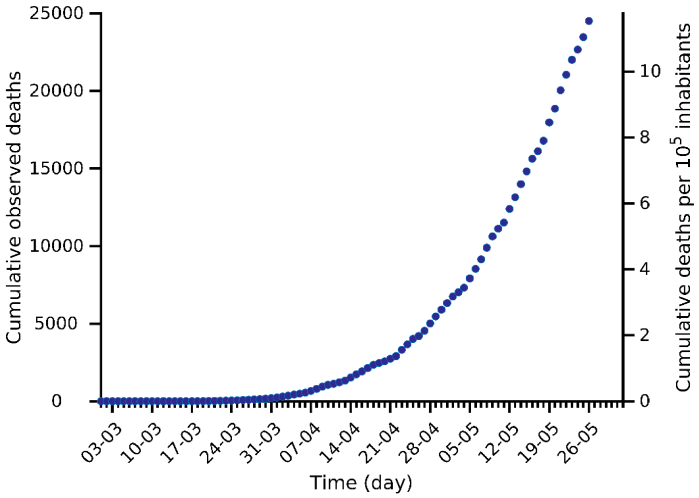



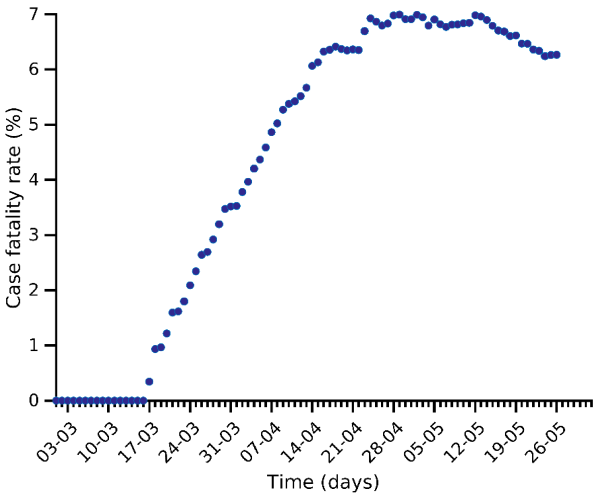



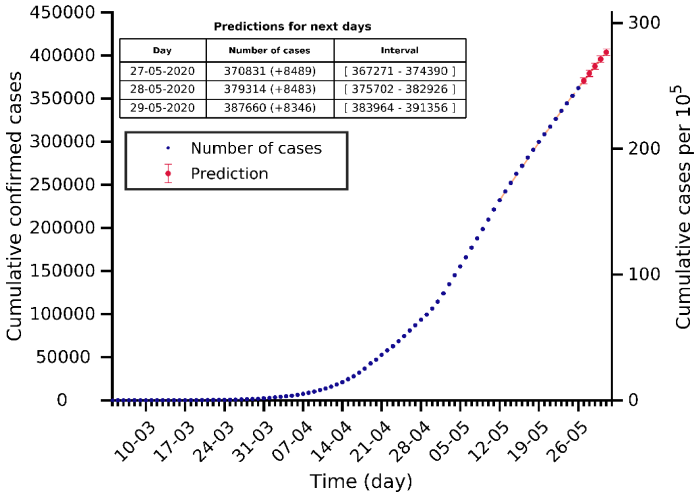



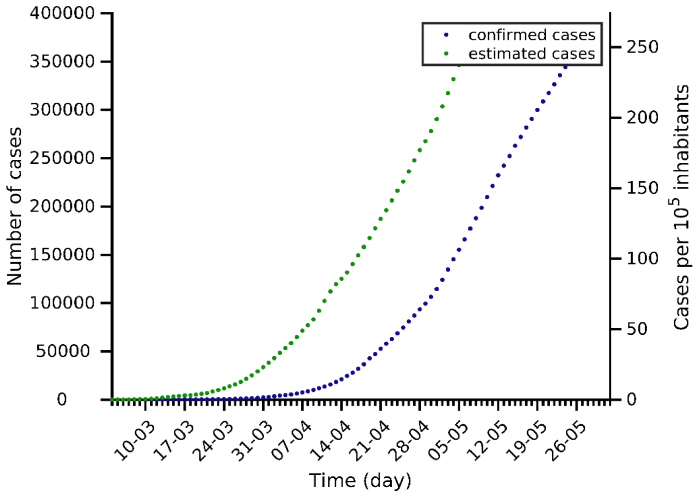



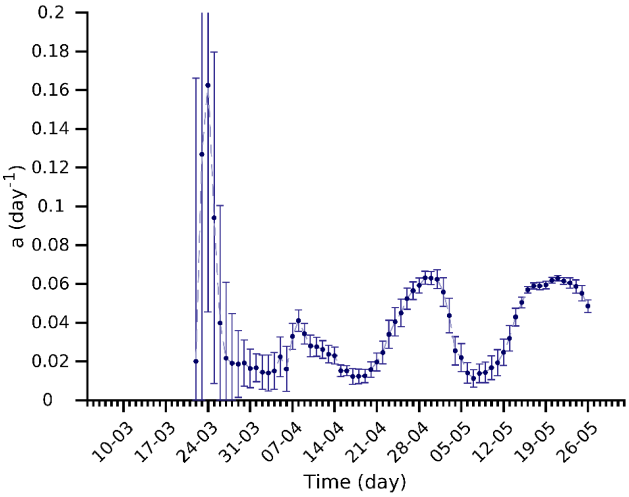



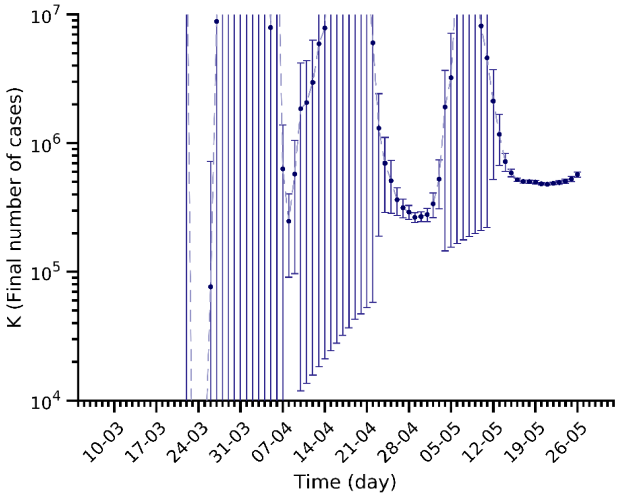



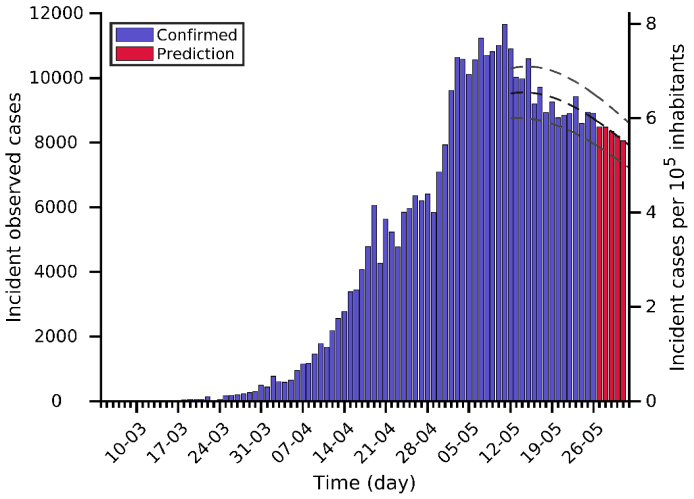
# Russia 26-05-2020. Population: 145.9M. Current cumulated incidence: 248/$10^5$

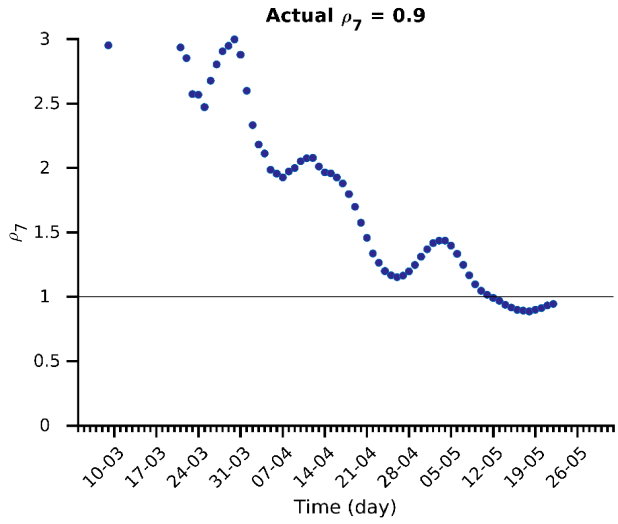


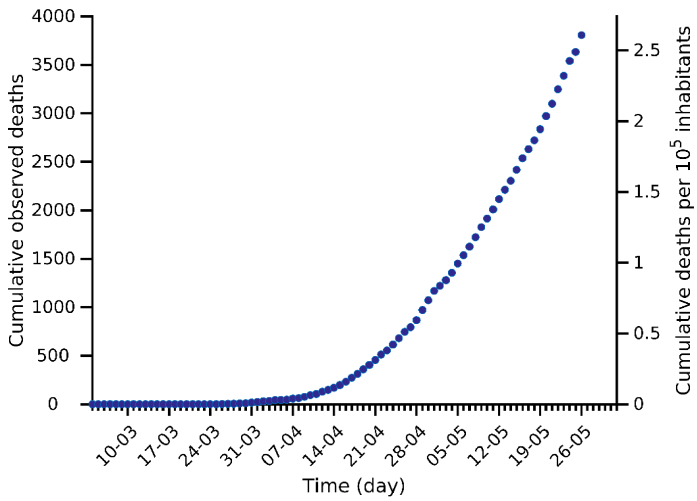



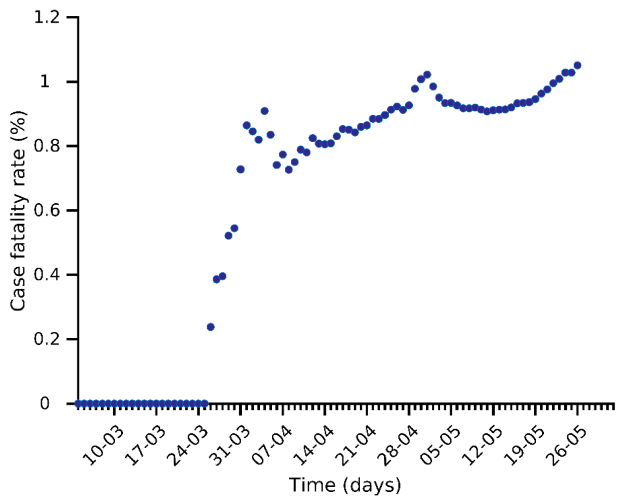



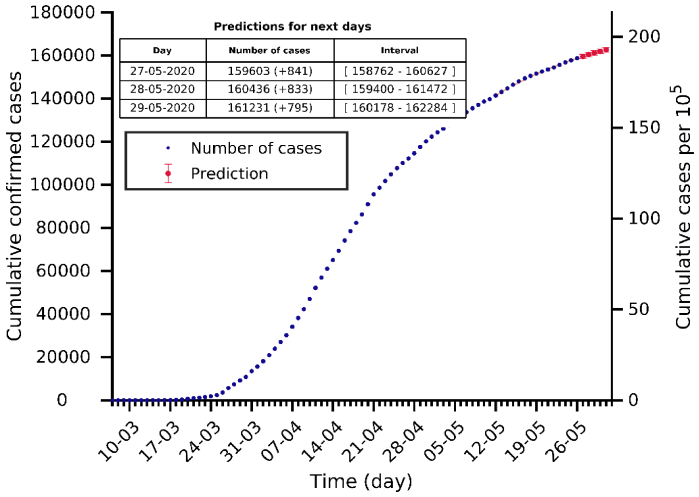



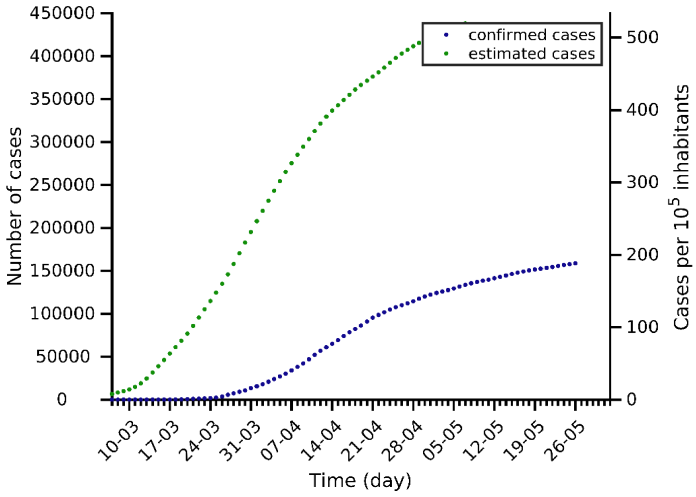



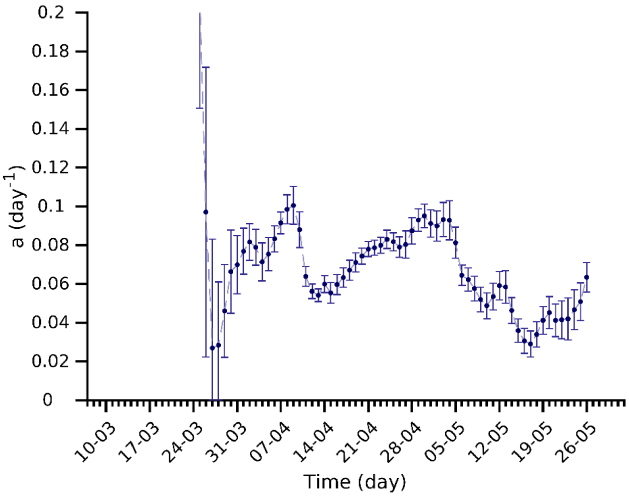



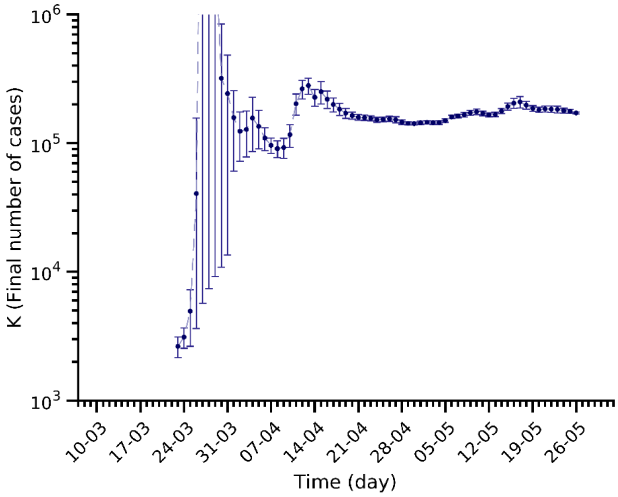



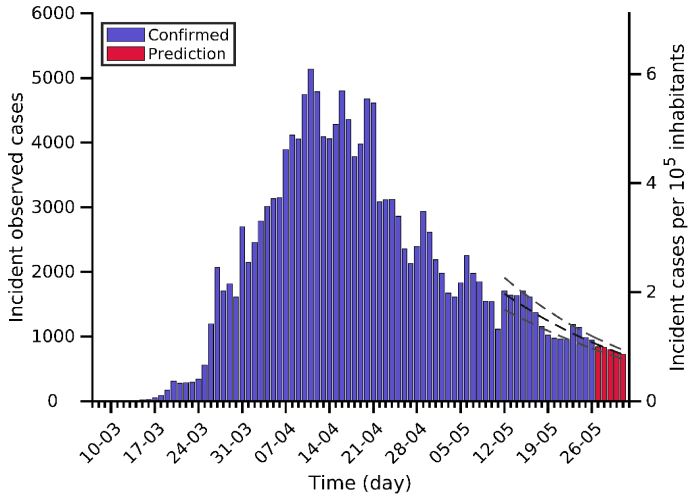
# Turkey 26-05-2020. Population: 84.3M. Current cumulated incidence: 188/$10^5$

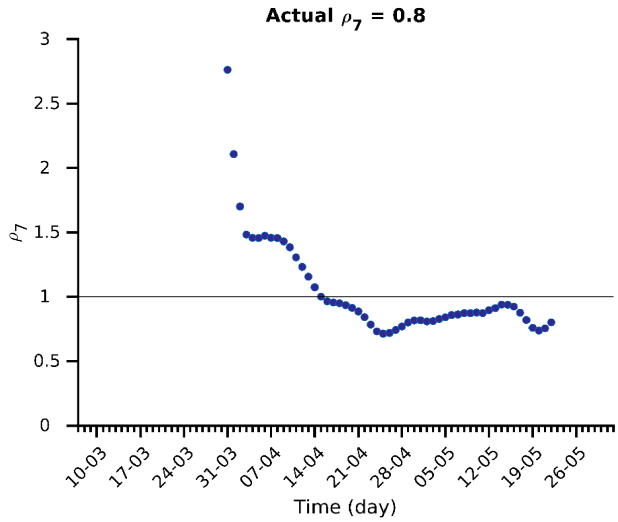


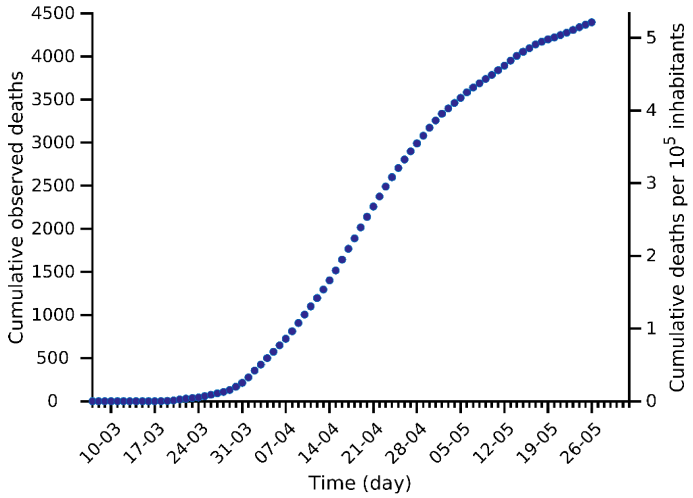



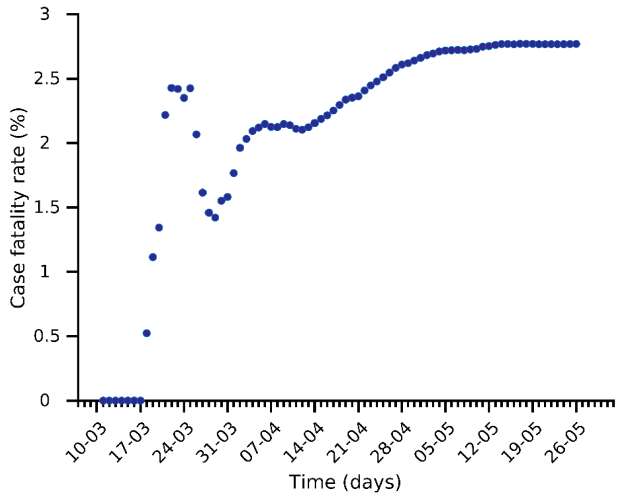



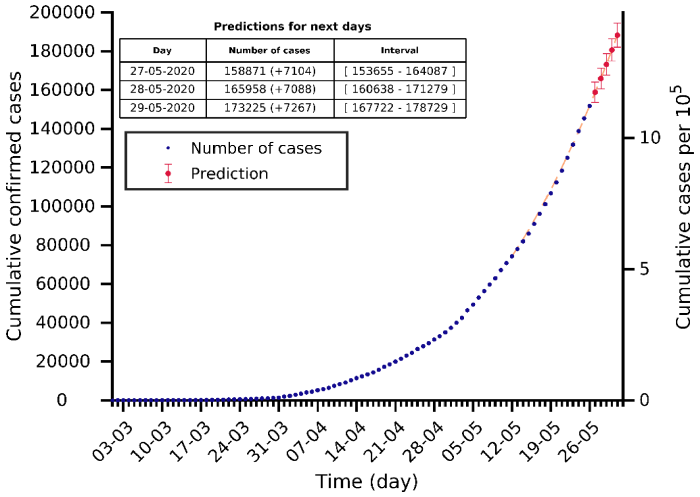



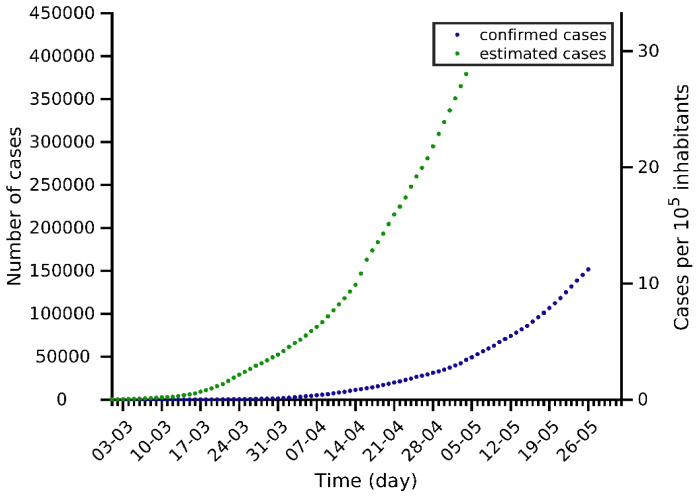



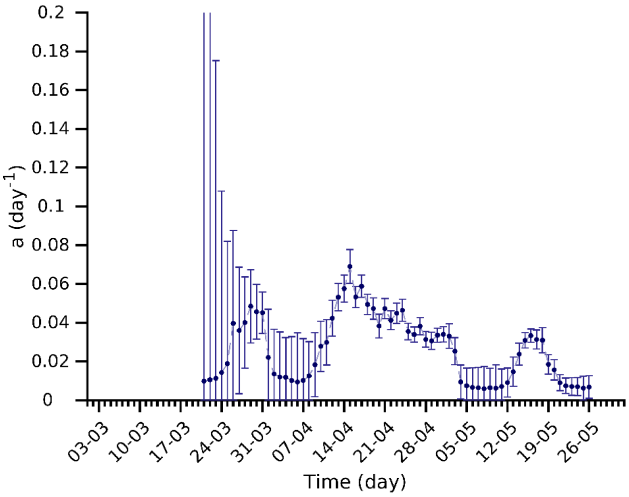



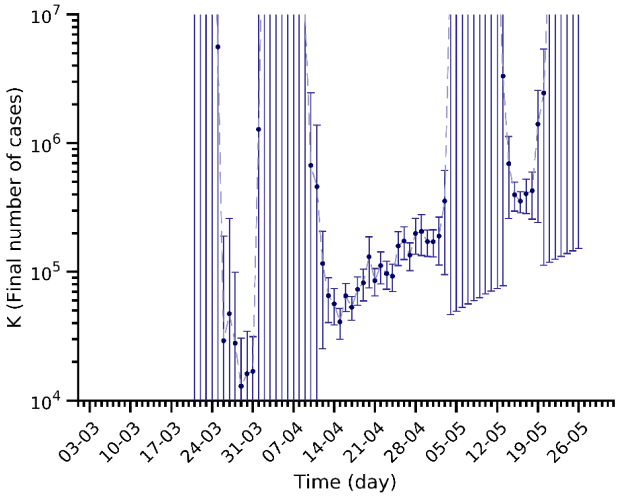



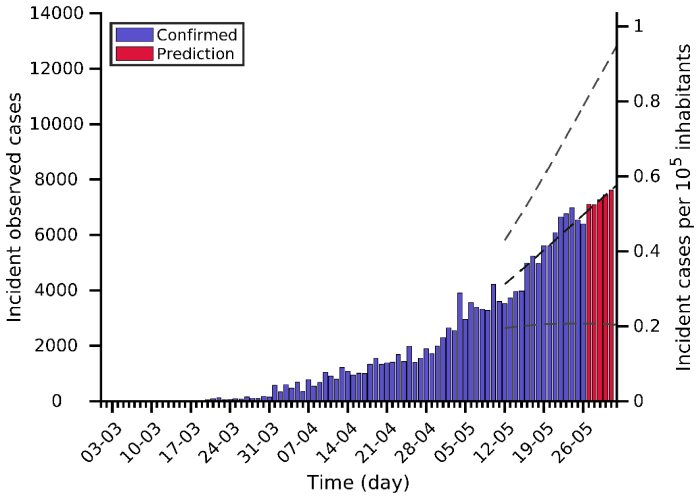
# India 26-05-2020. Population: 1353.0M. Current cumulated incidence: $11/10^5$

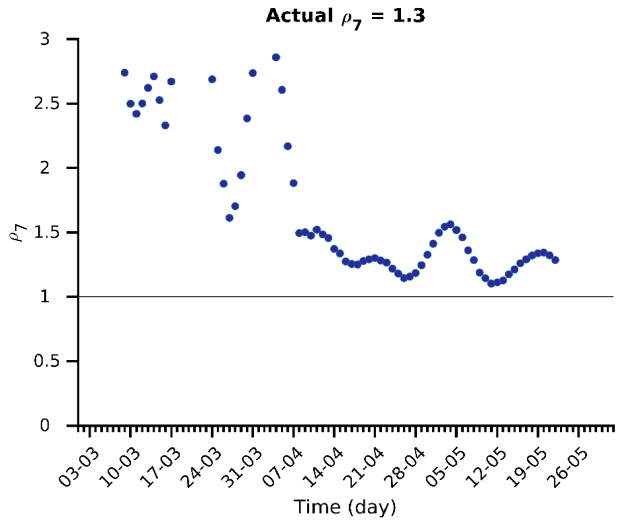


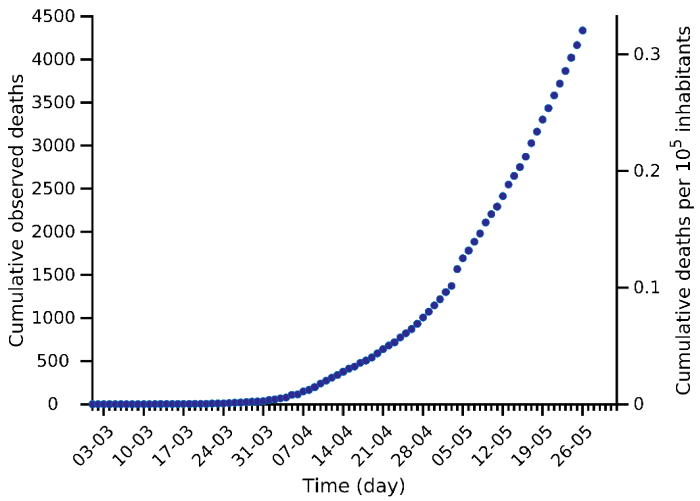



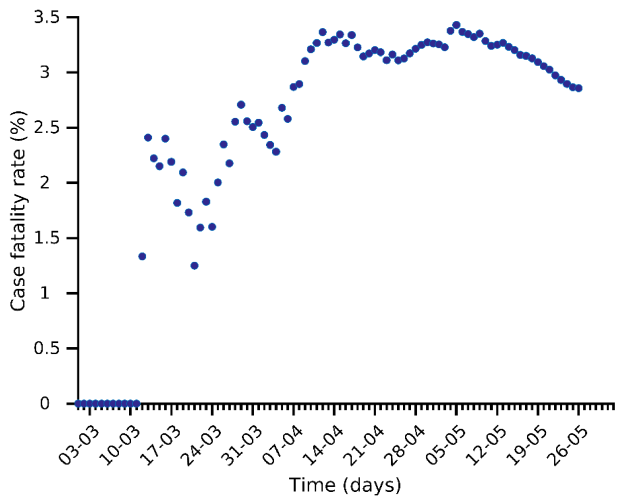



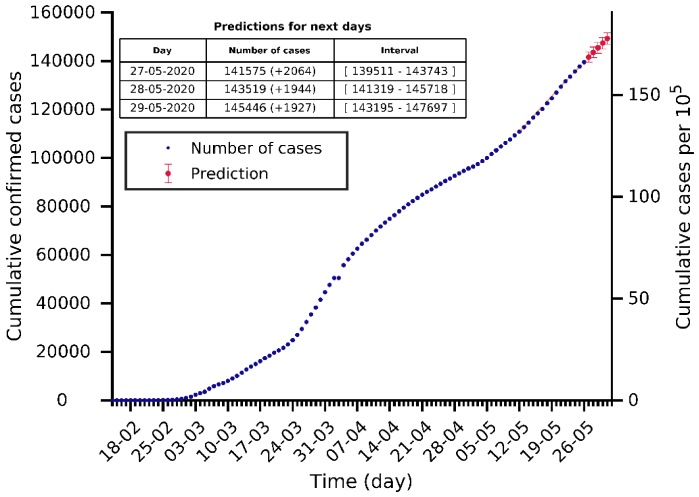



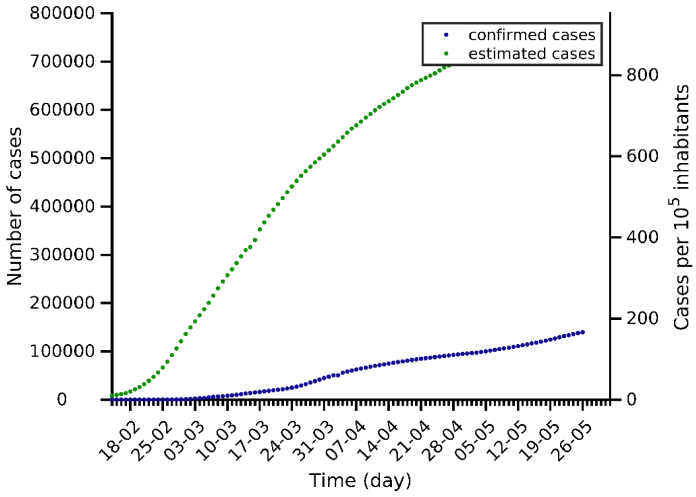



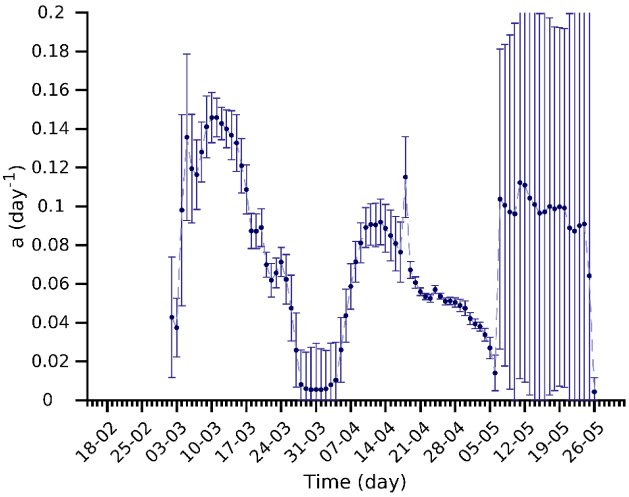



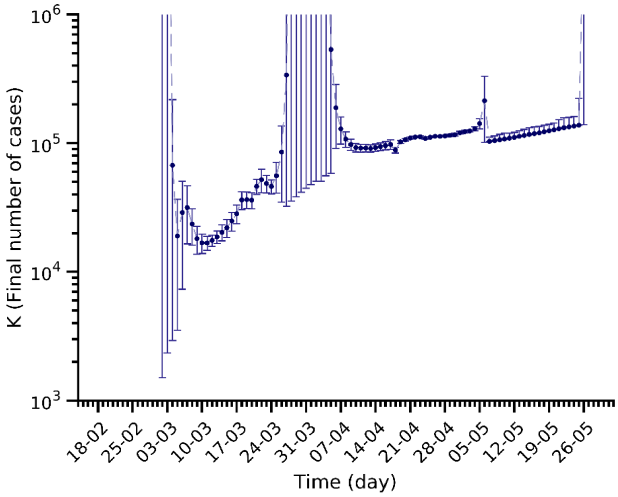



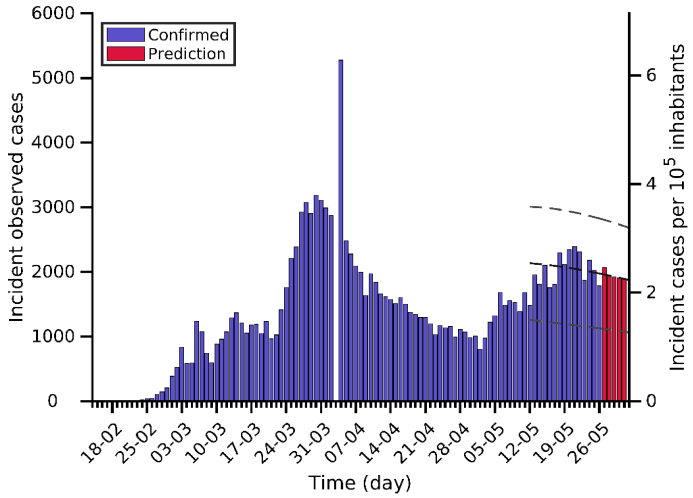
# Iran 26-05-2020. Population: 84.0M. Current cumulated incidence: 166/$10^5$

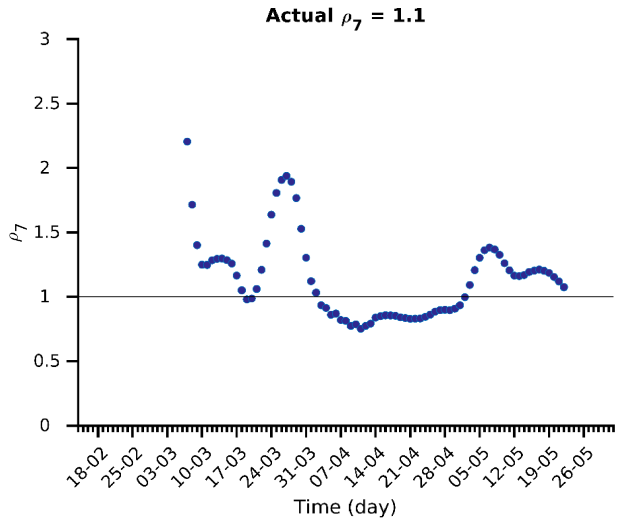


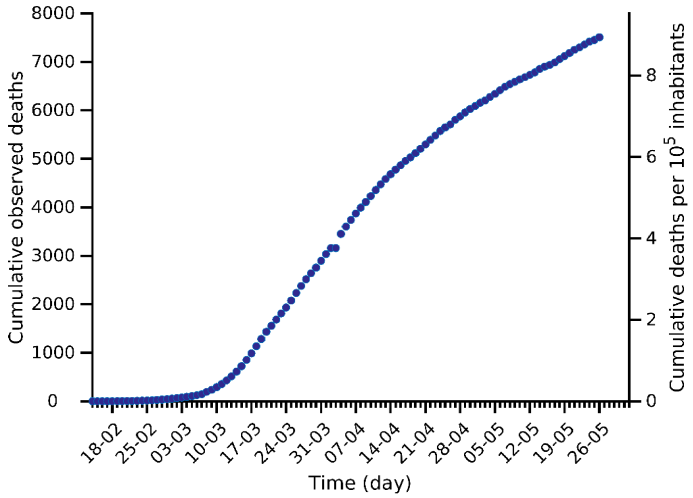



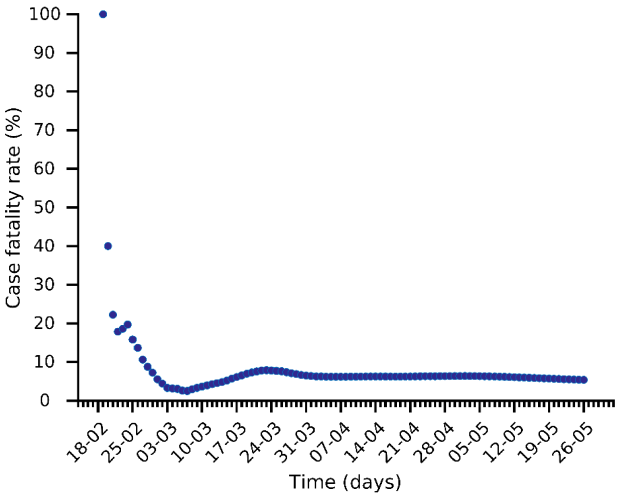



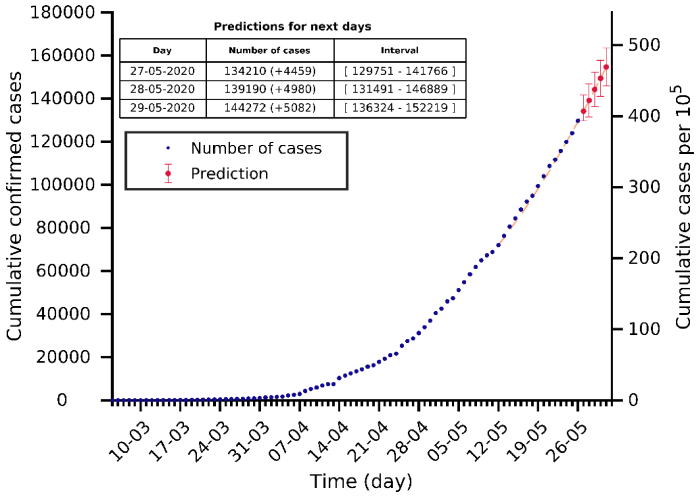



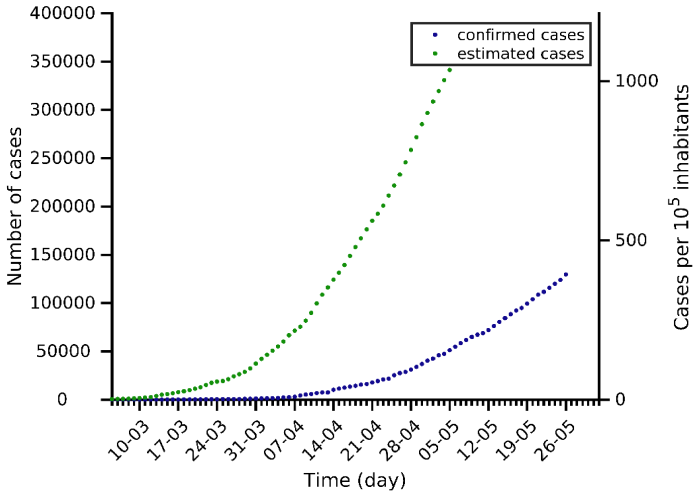



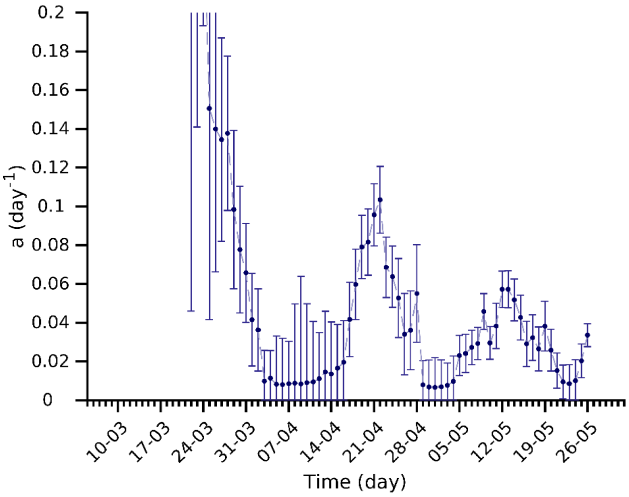



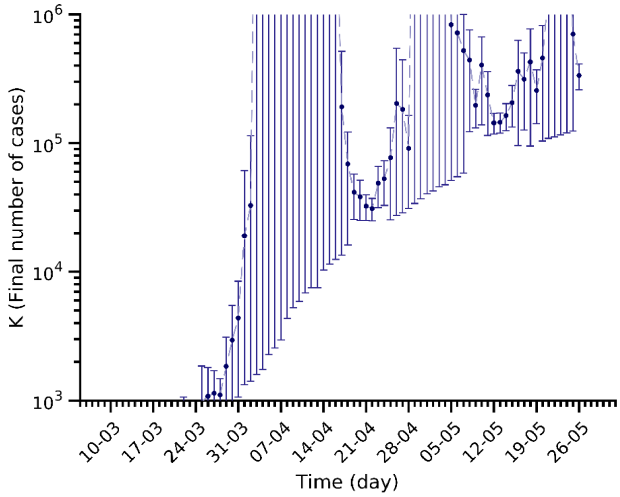



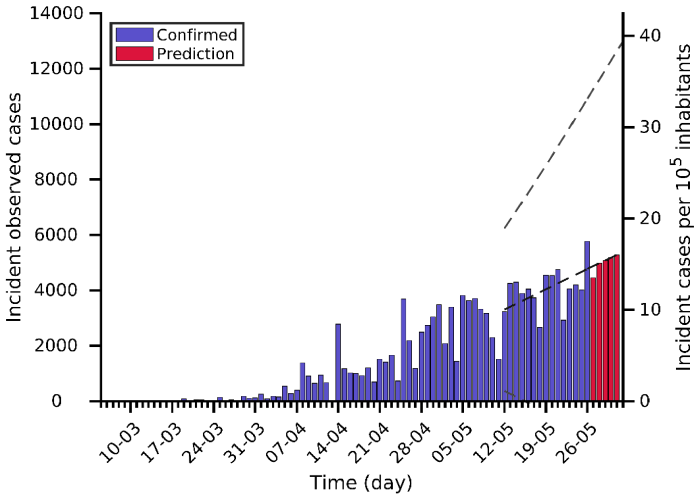
# Peru 26-05-2020. Population: 33.0M. Current cumulated incidence: 394/$10^5$

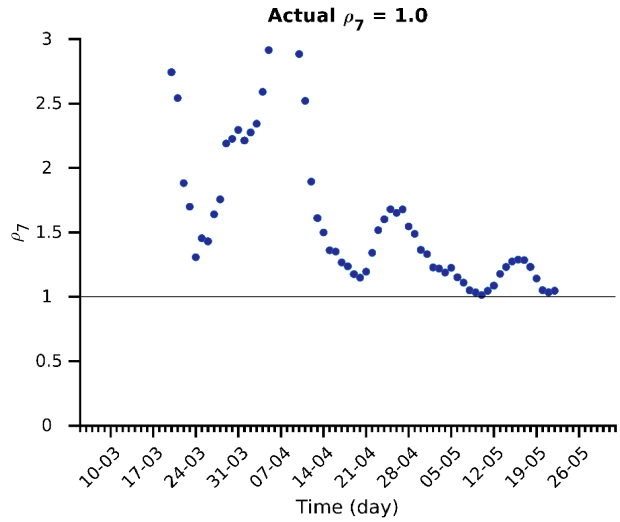


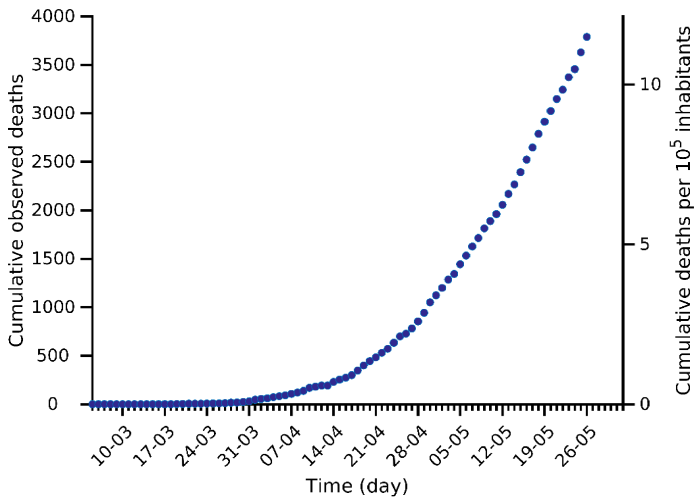



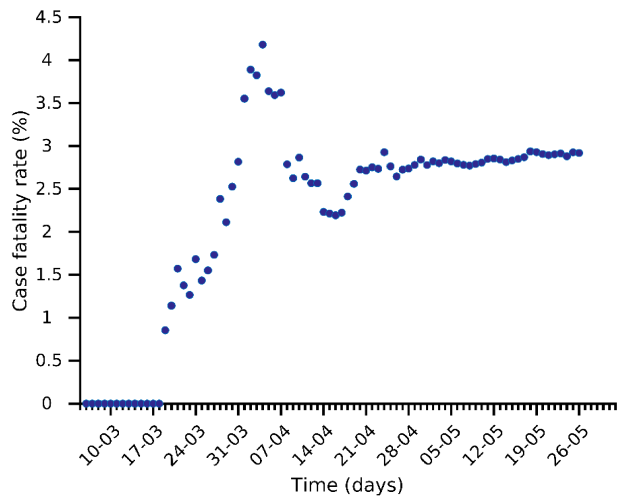



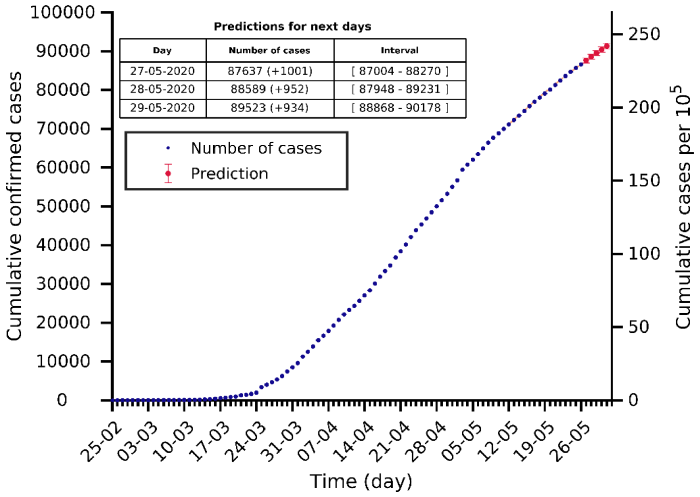



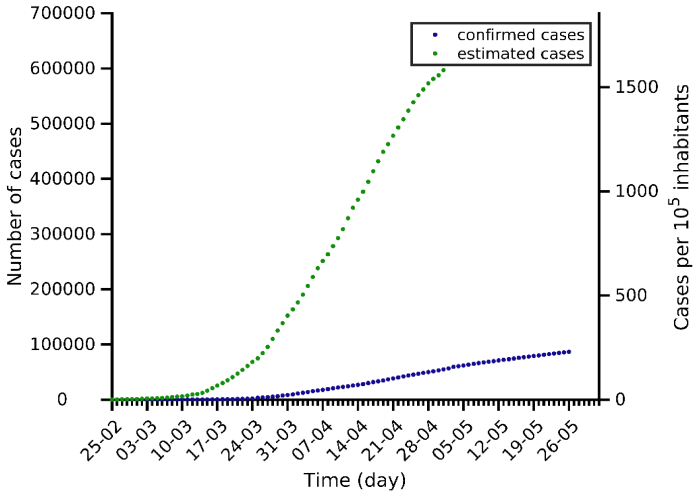



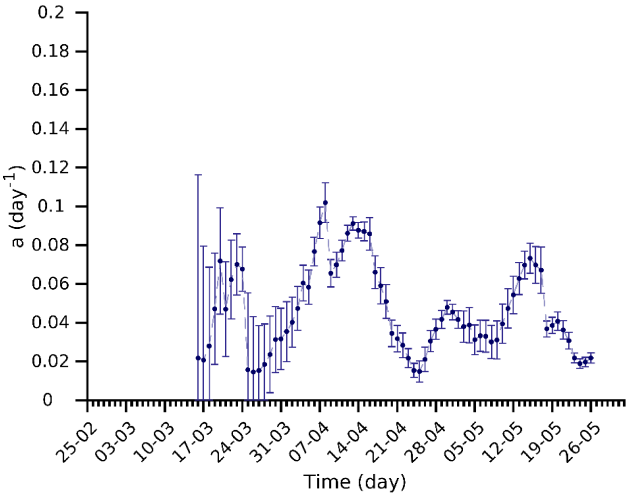



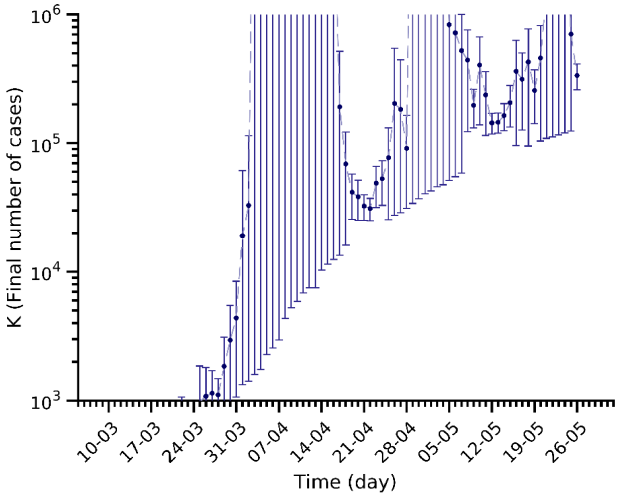



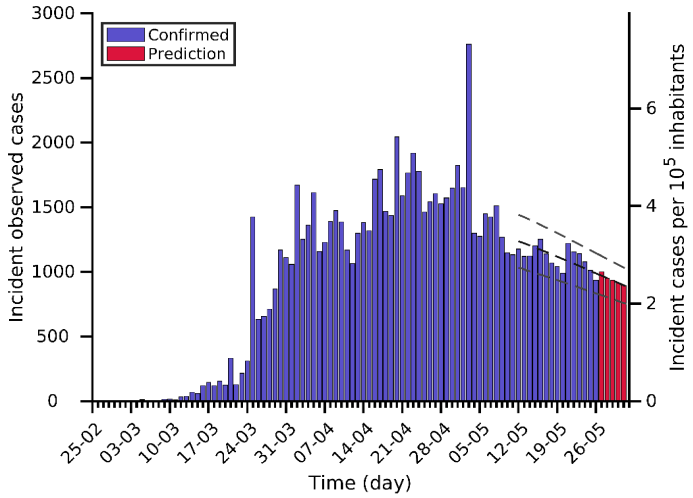
# Canada 26-05-2020. Population: 37.7M. Current cumulated incidence: 230/$10^5$

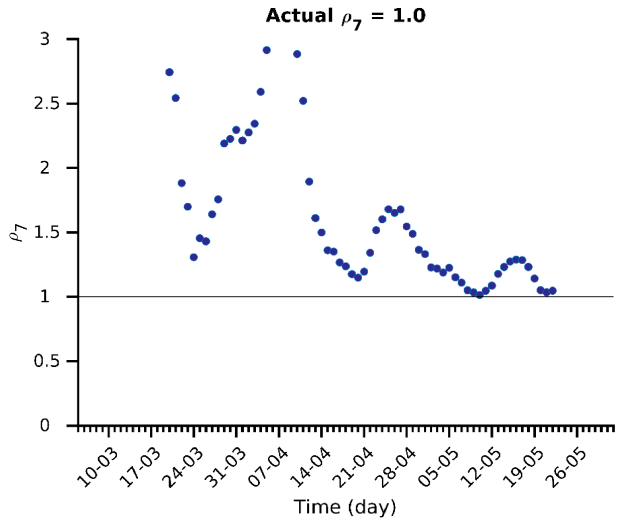


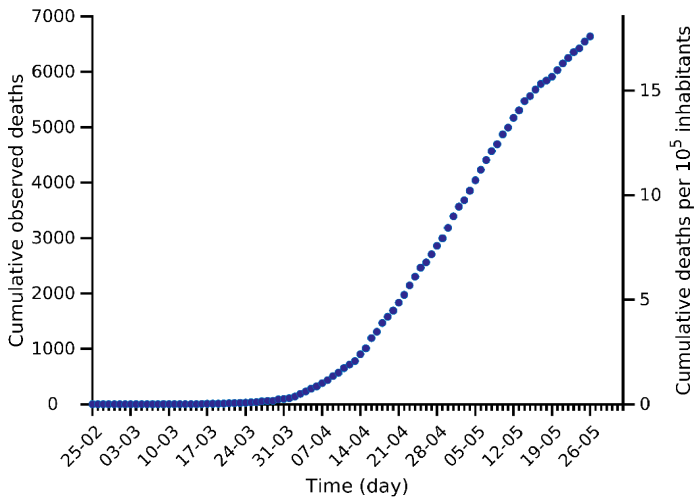



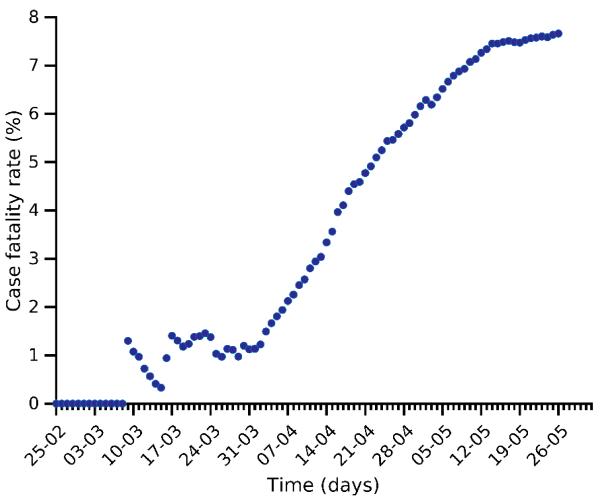



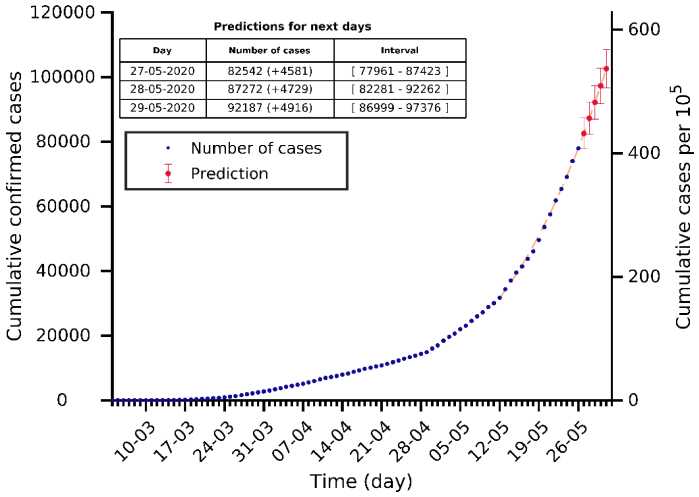



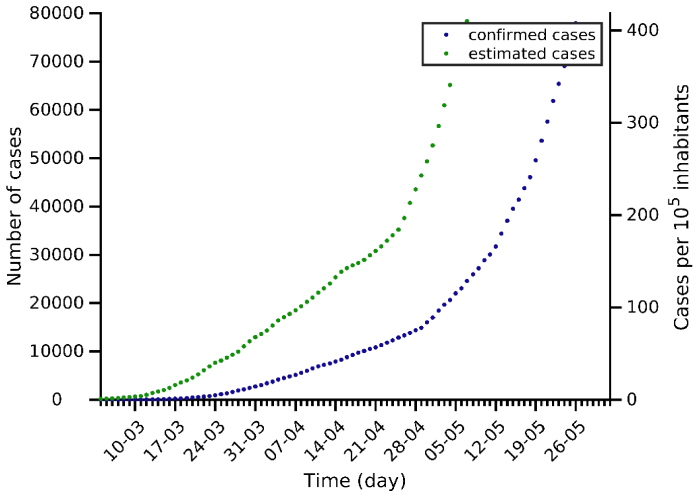



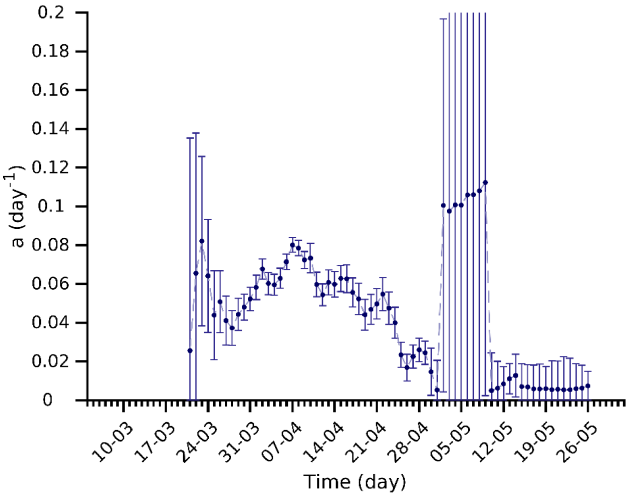



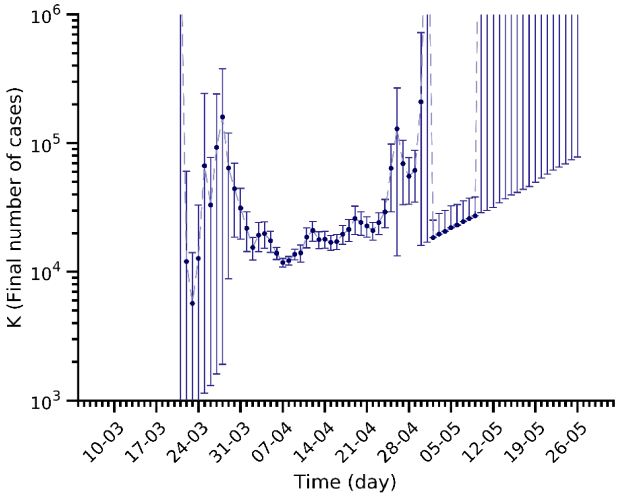



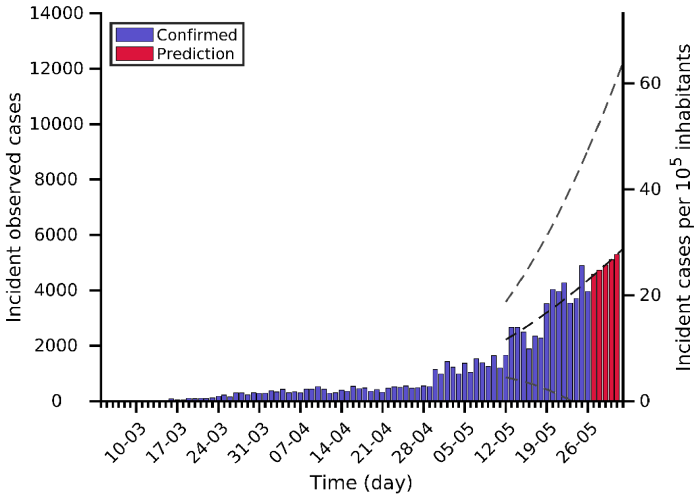
# Chile 26-05-2020. Population: 19.1M. Current cumulated incidence: 408/$10^5$

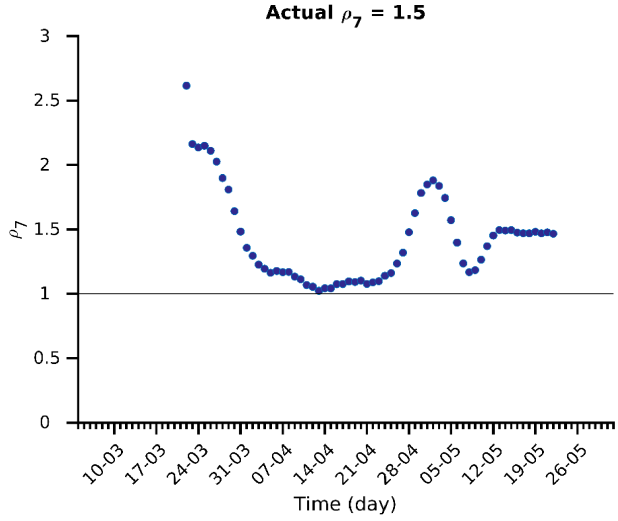


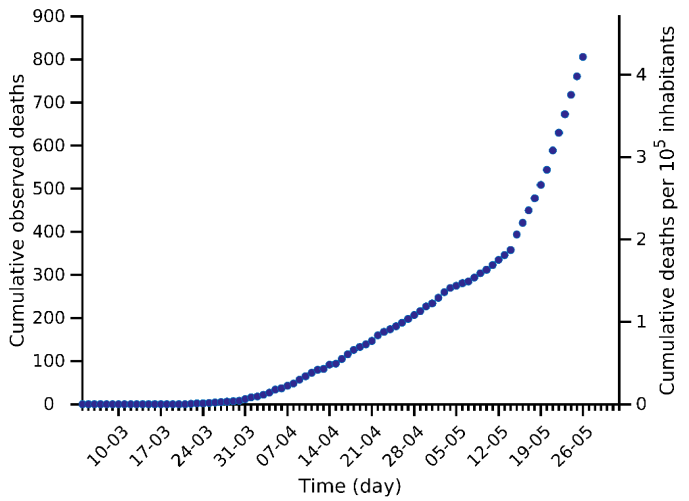



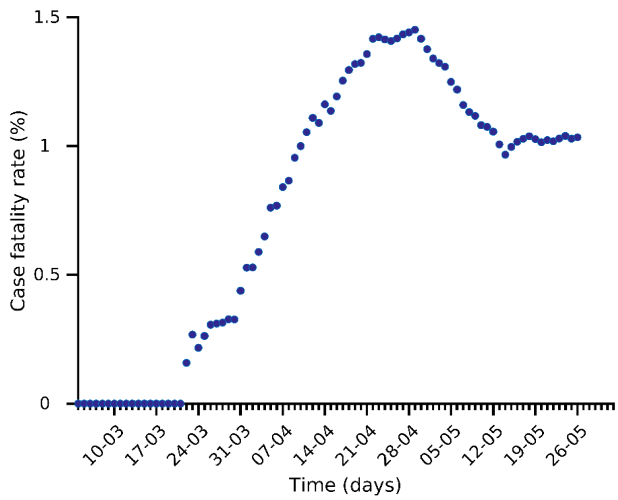



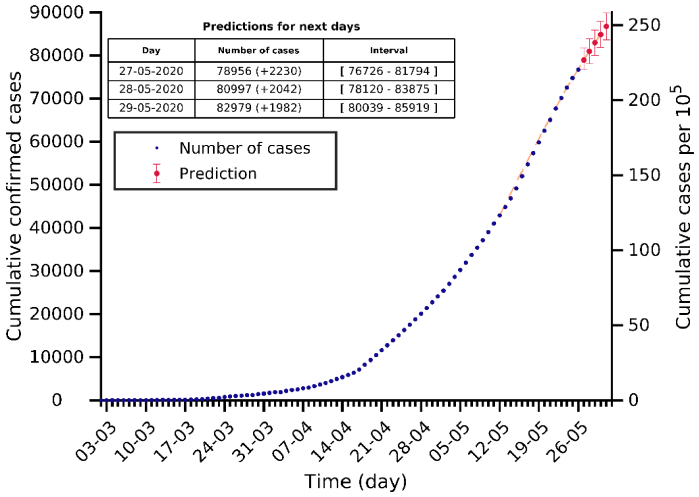



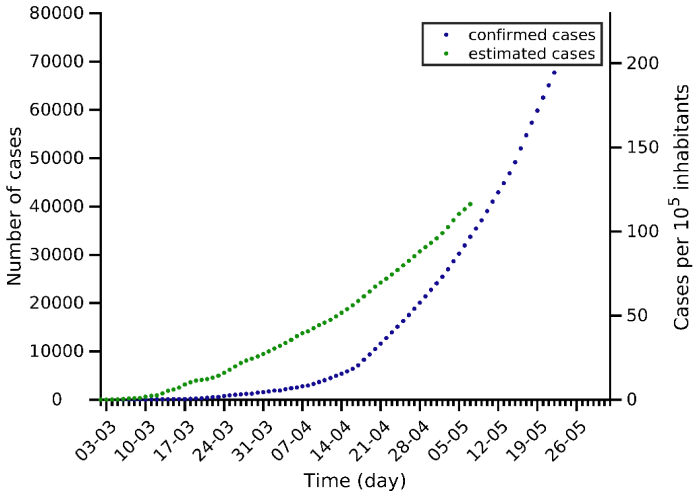



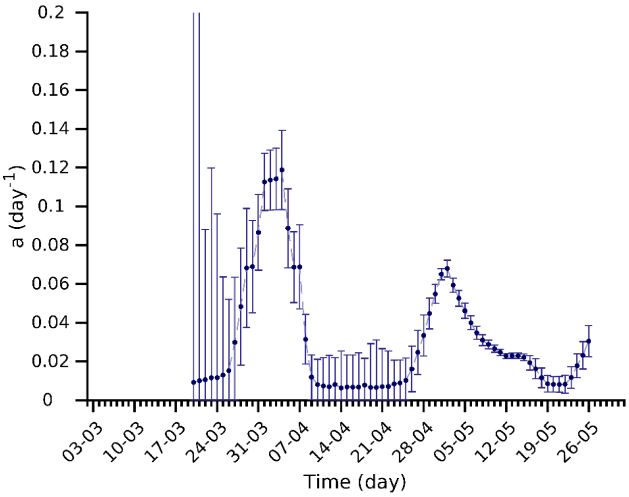



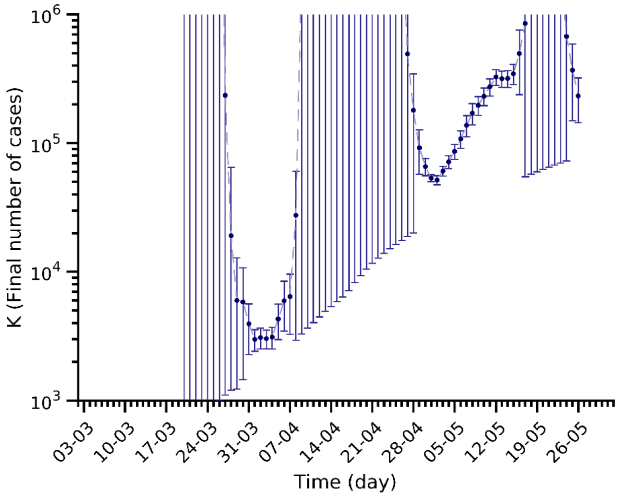



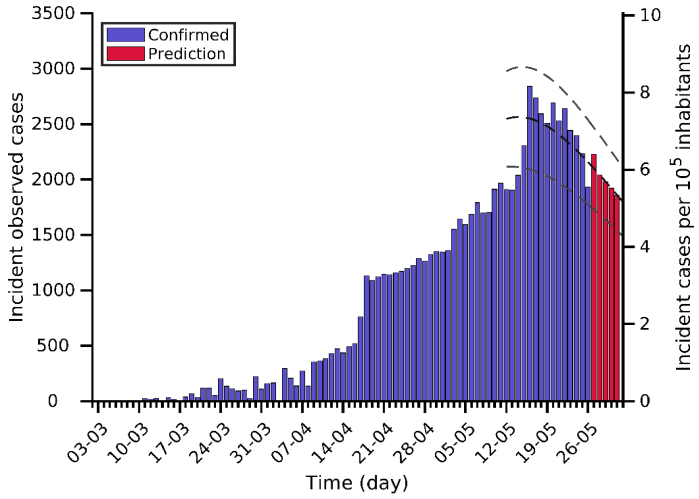
# Saudi Arabia  26-05-2020. Population: 34.8M. Current cumulated incidence: 220/10$^5$

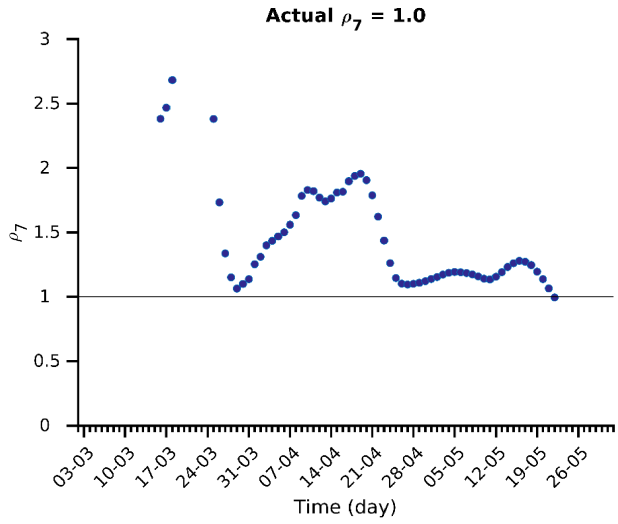


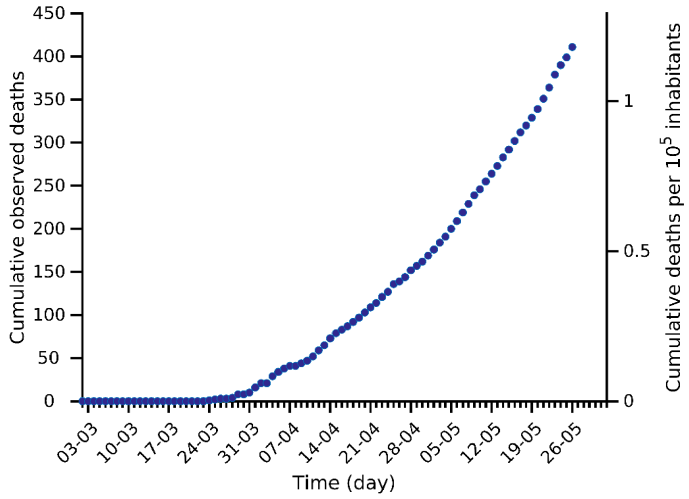



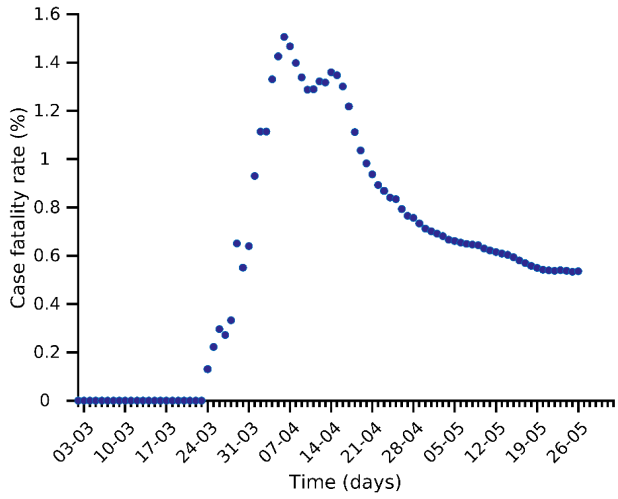



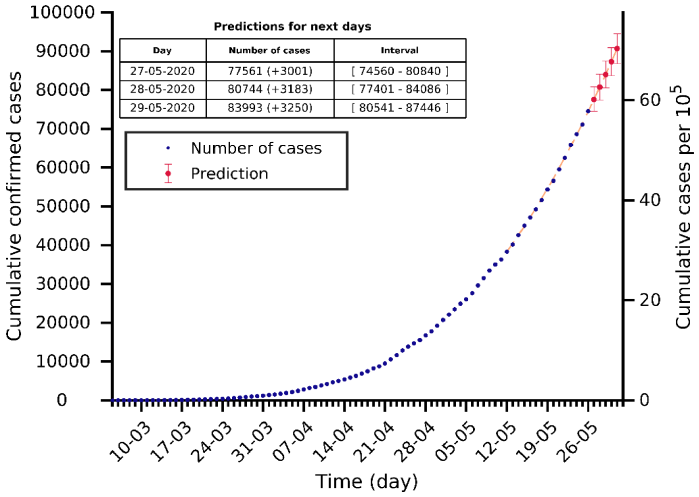



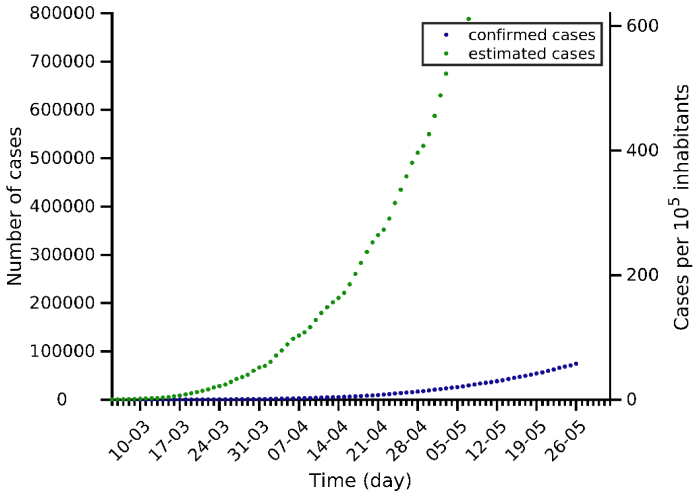



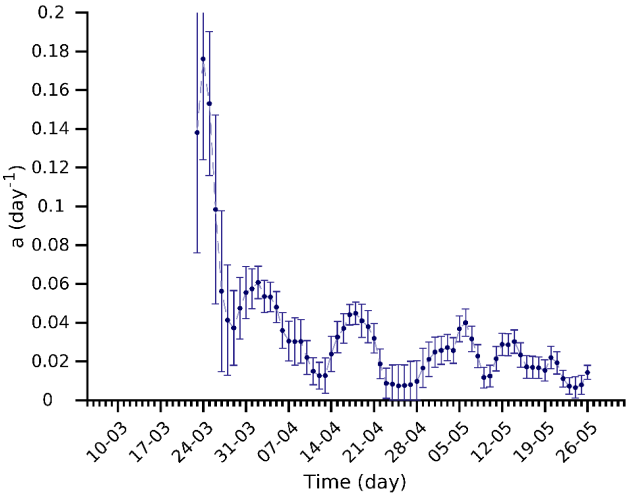



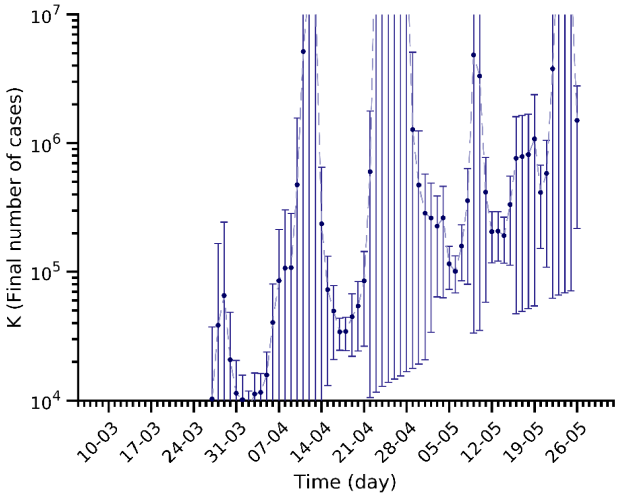



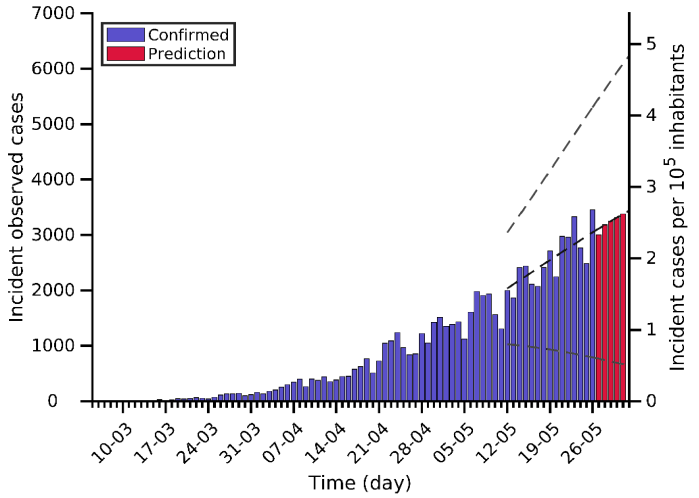
# Mexico 26-05-2020. Population: 128.9M. Current cumulated incidence: $58/10^5$

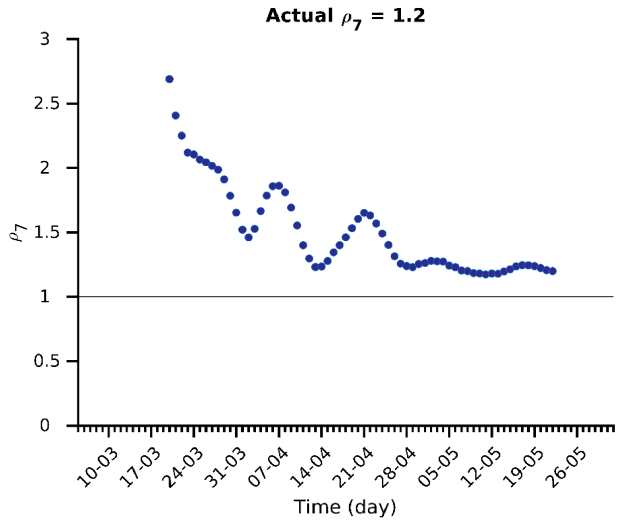


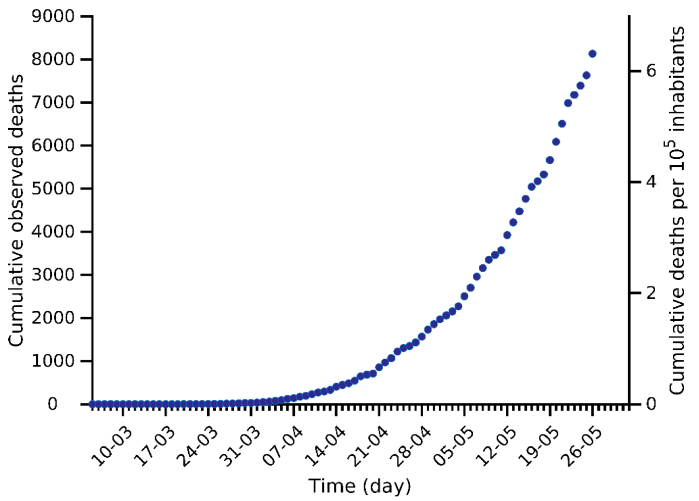



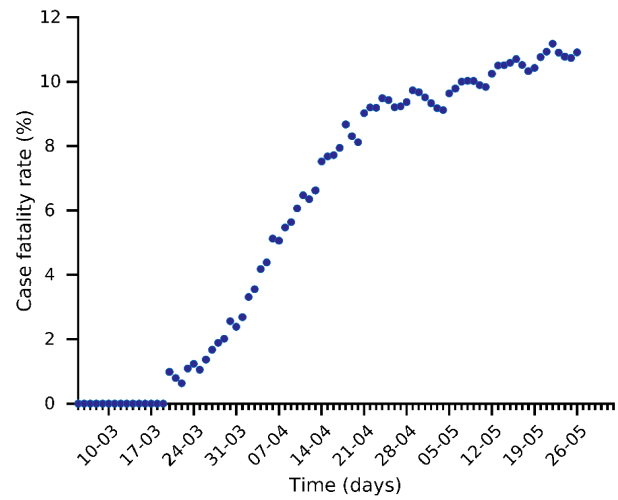



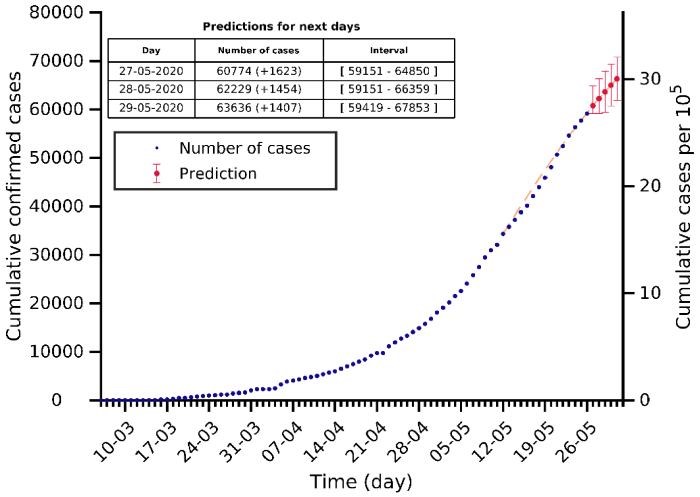



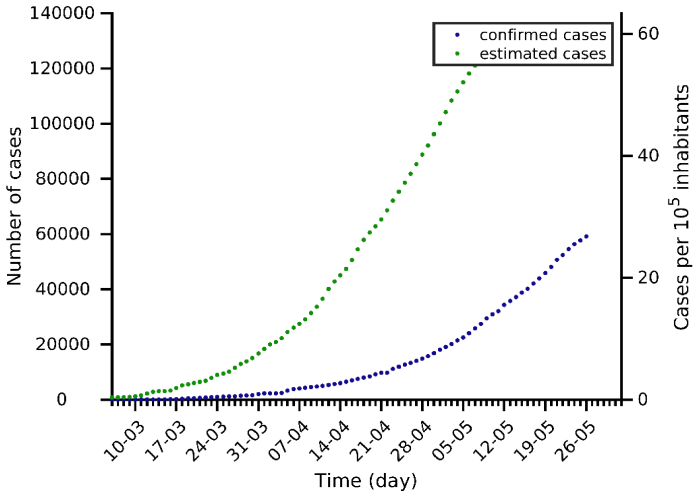



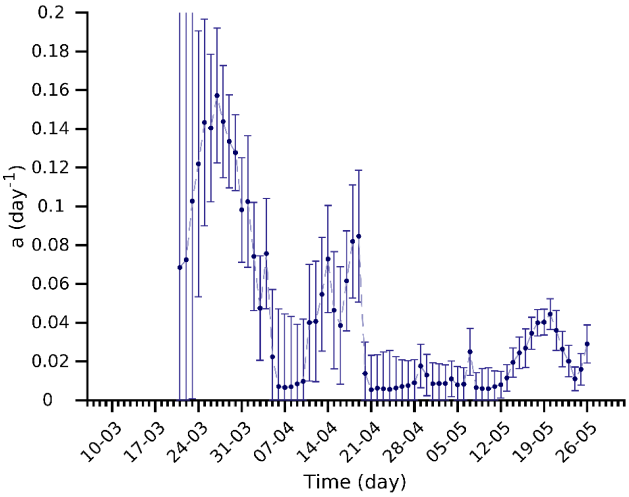



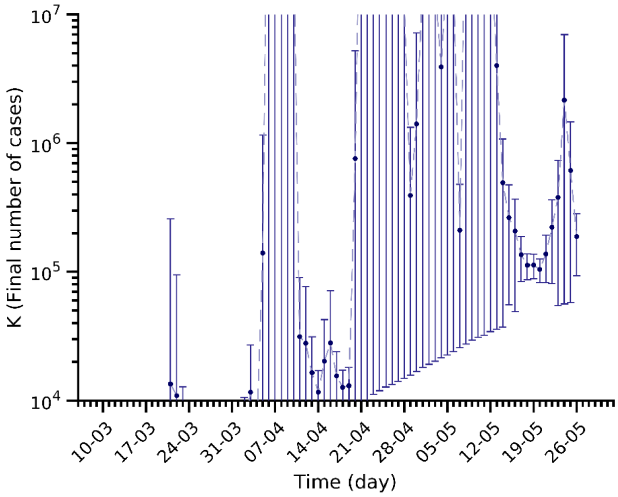



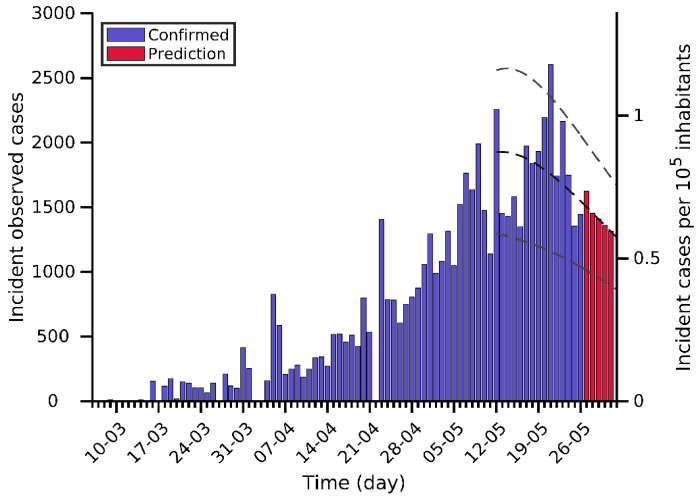
# Pakistan 26-05-2020. Population: 220.9M. Current cumulated incidence: 27/10⁵

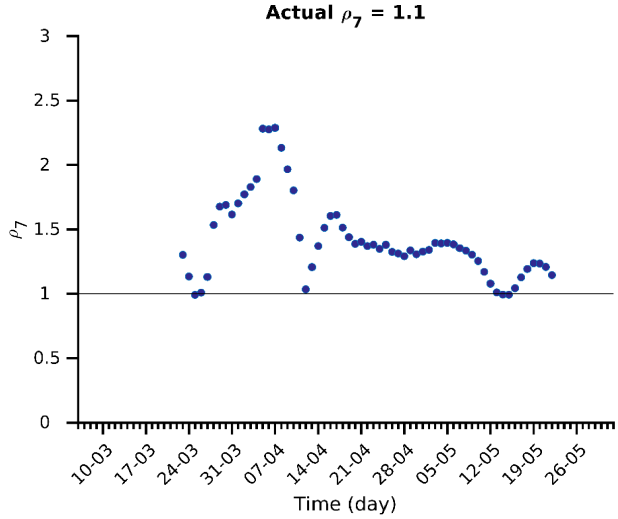


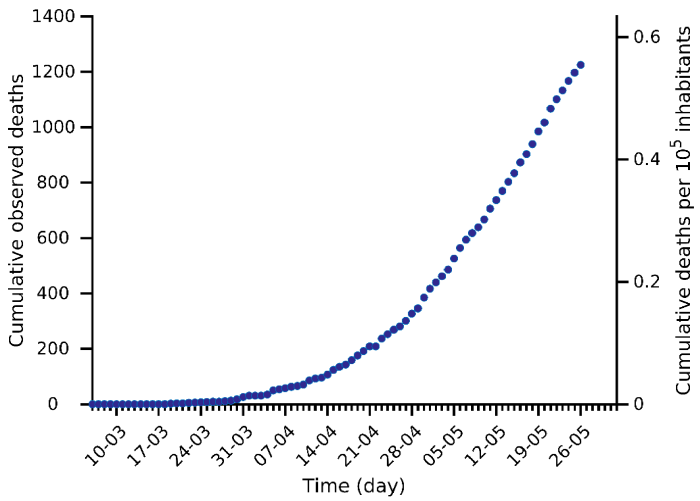



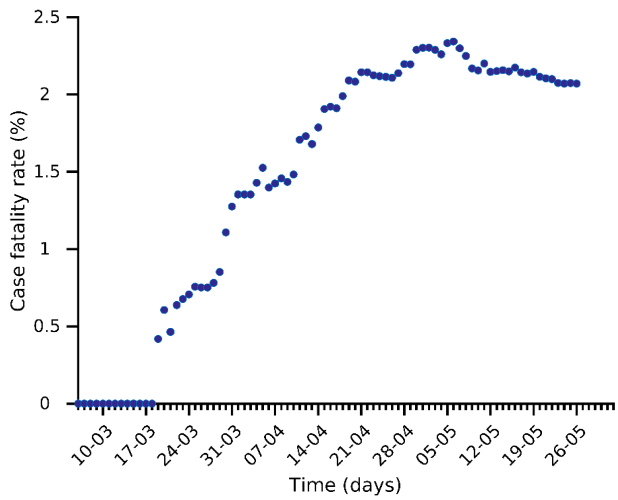



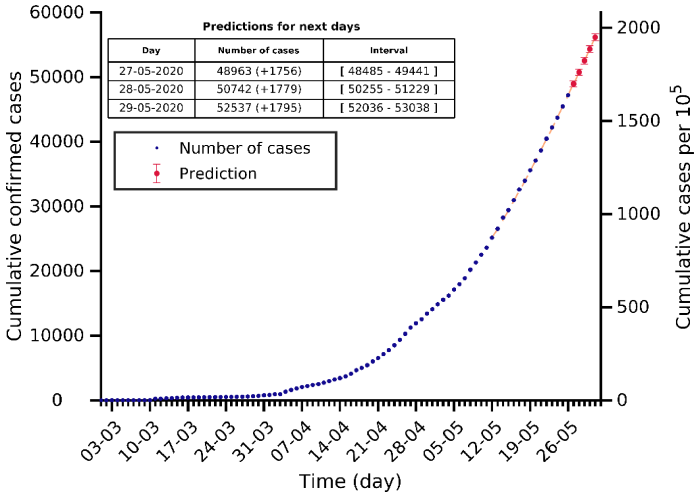



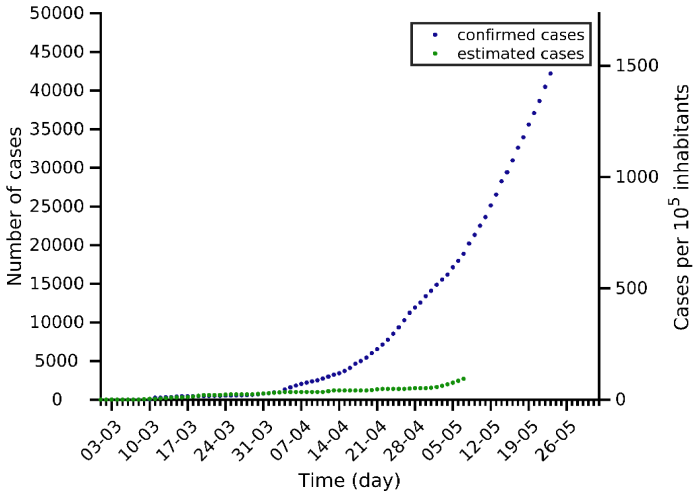



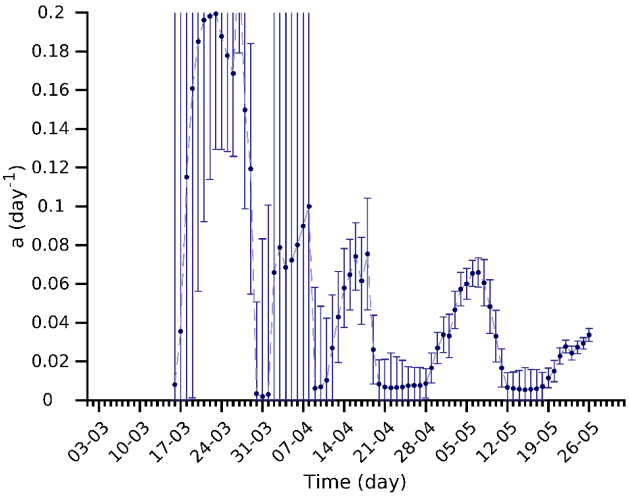



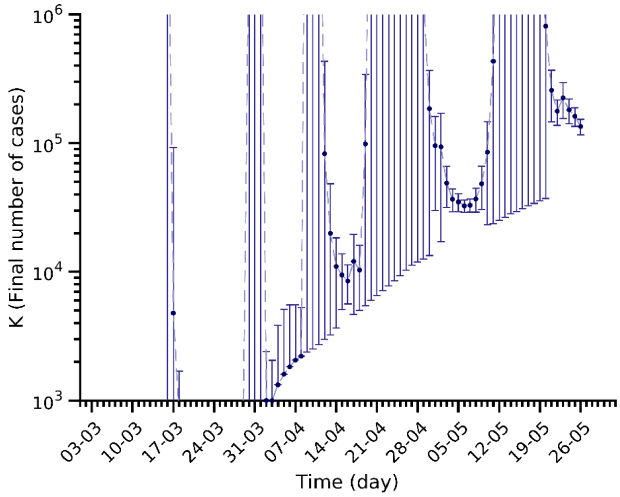



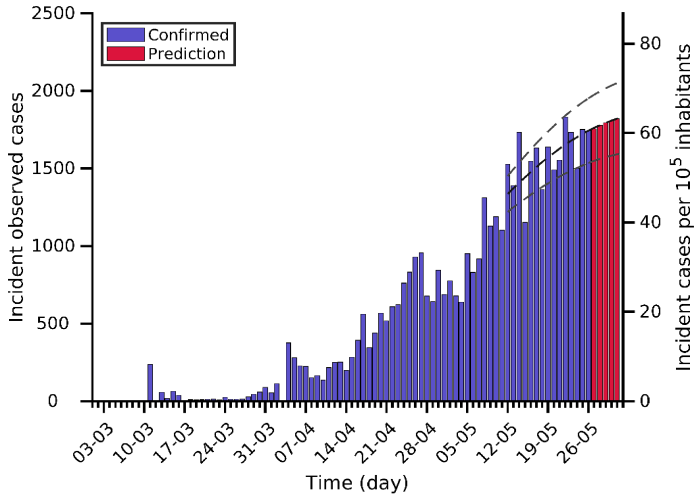
# Qatar 26-05-2020. Population: 2.9M. Current cumulated incidence: 1639/$10^5$

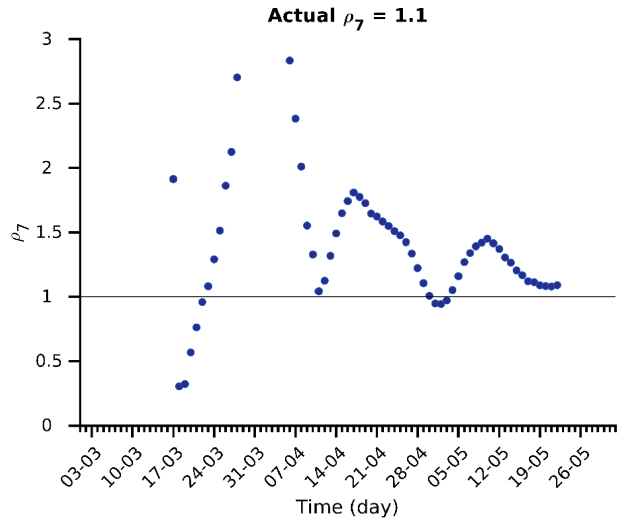


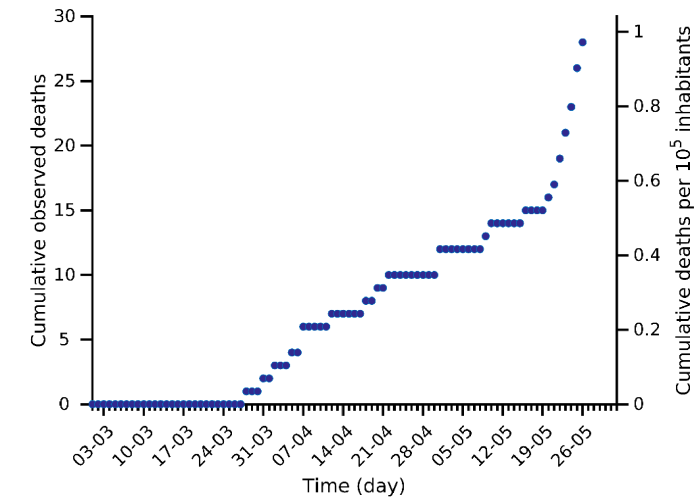



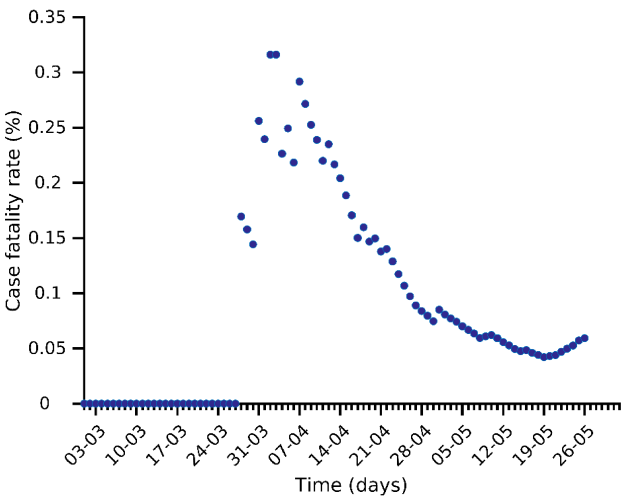



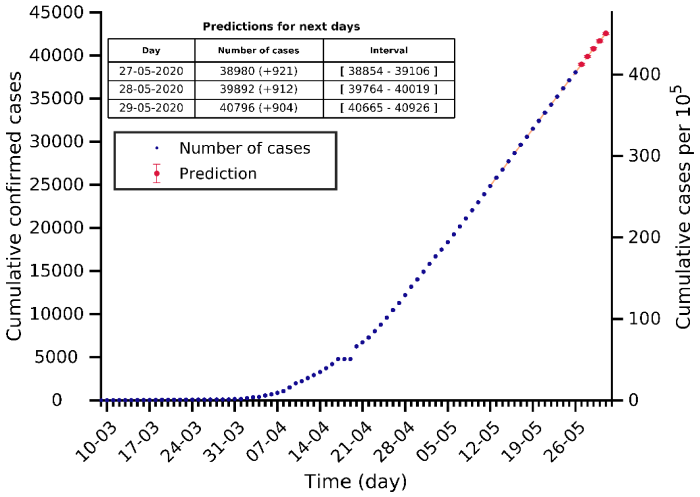



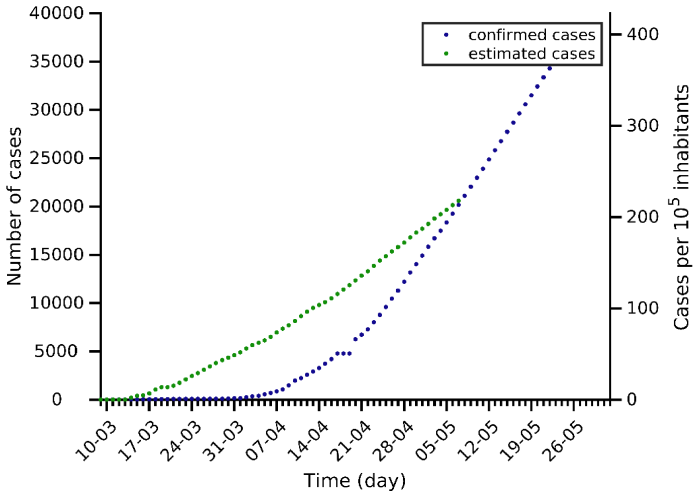



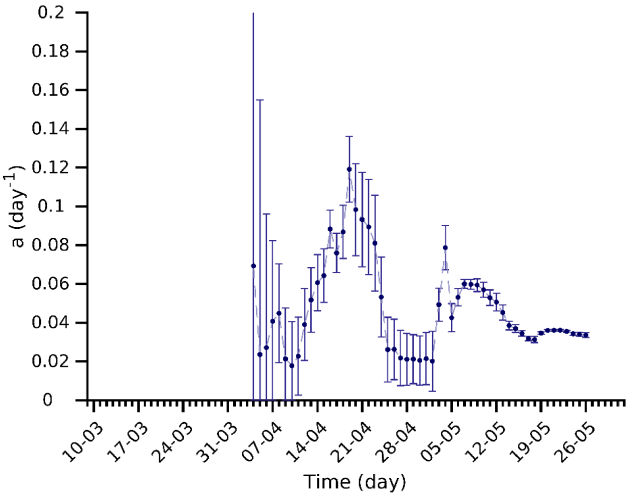



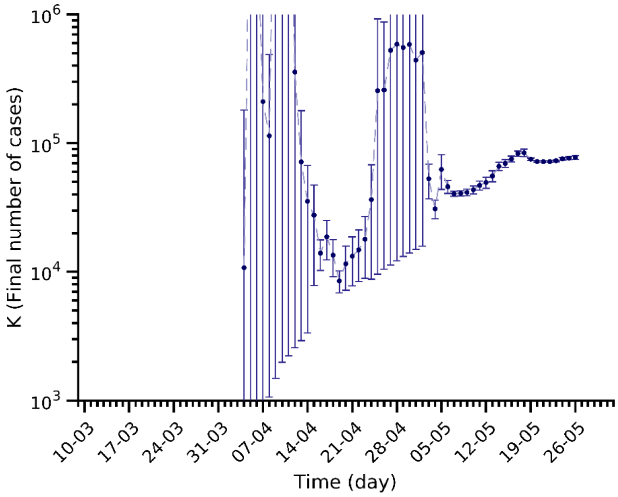



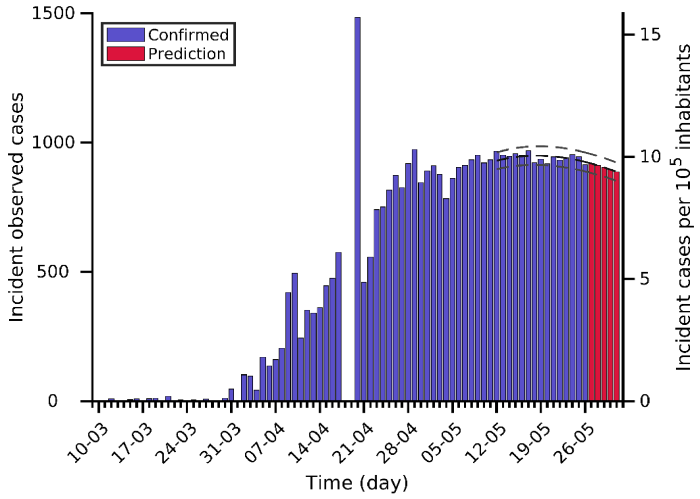
# Belarus 26-05-2020. Population: 9.4M. Current cumulated incidence: 403/$10^5$

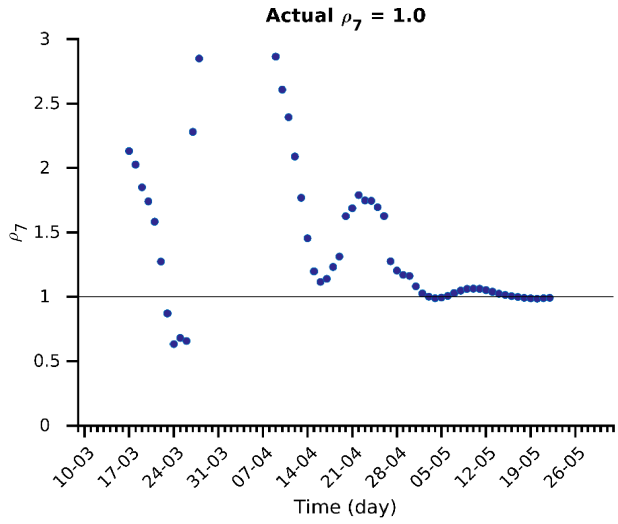


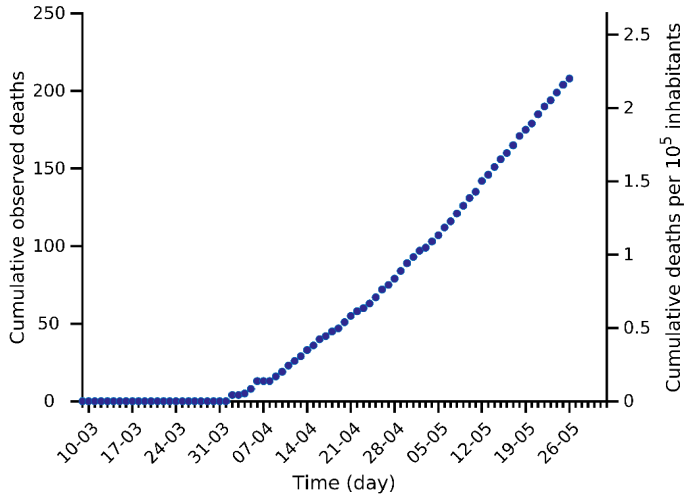



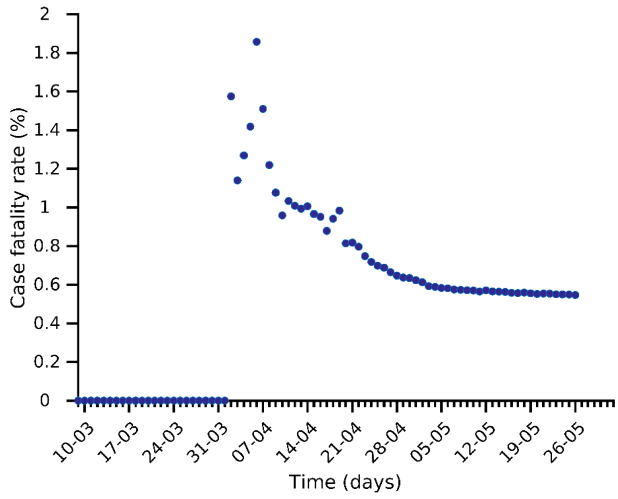



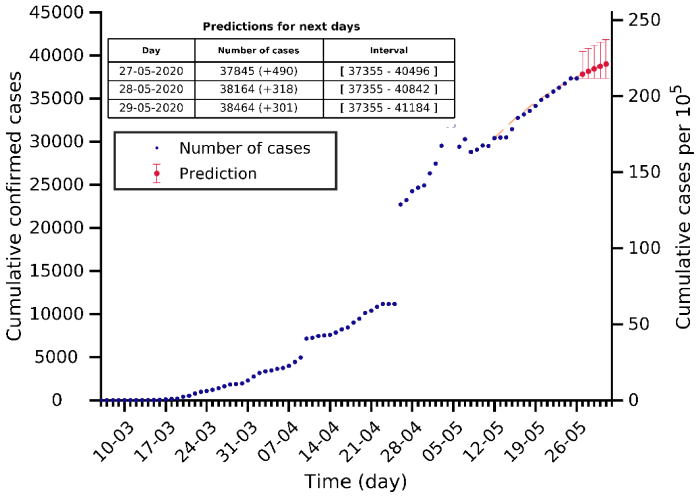



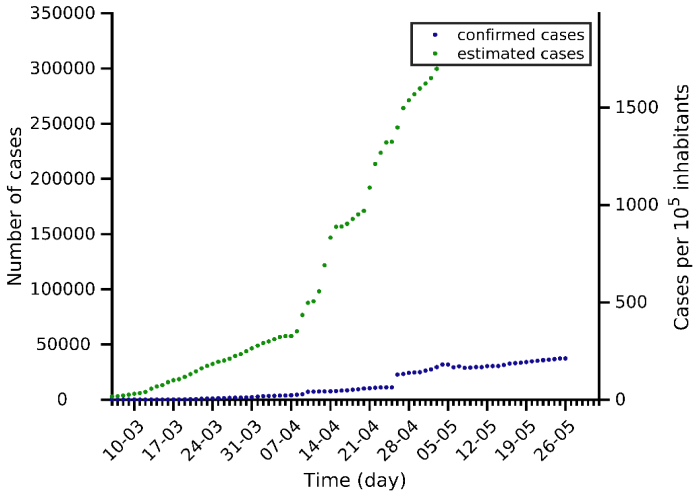



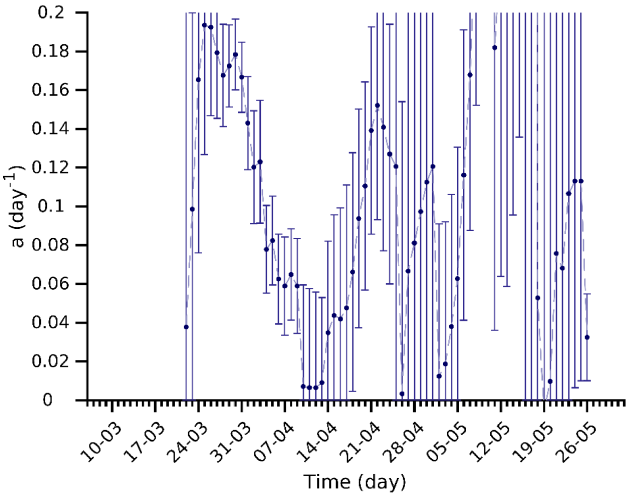



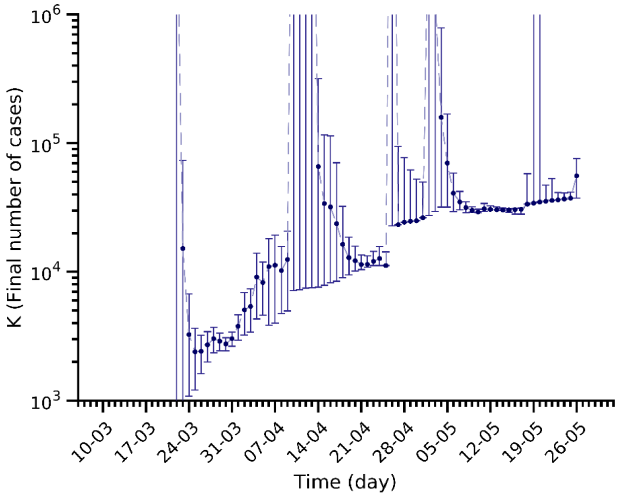



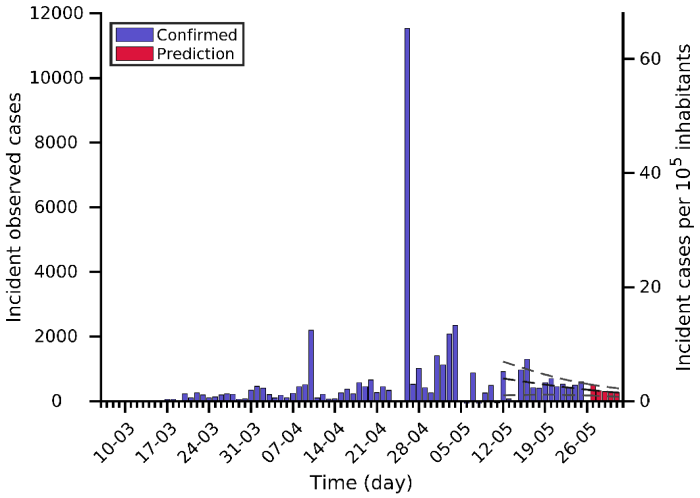
# Ecuador 26-05-2020. Population: 17.6M. Current cumulated incidence: 212/$10^5$

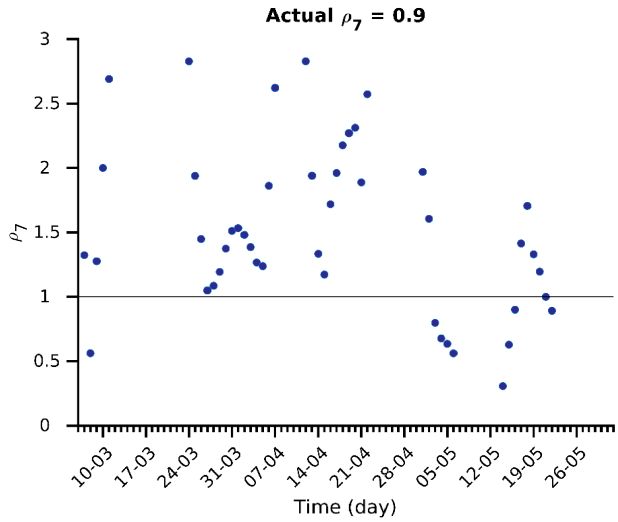


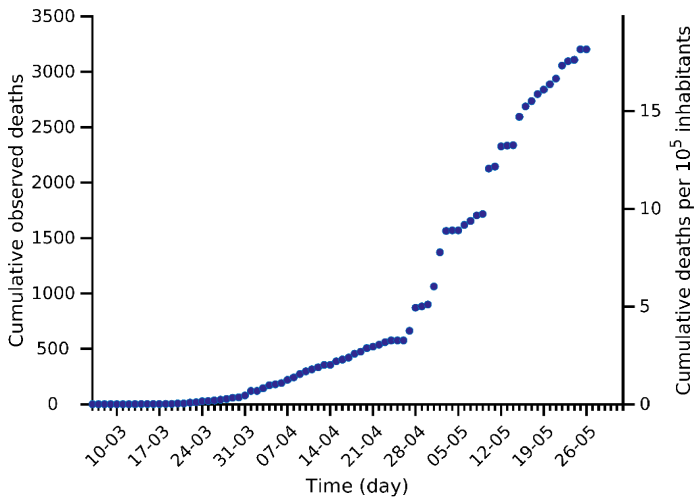



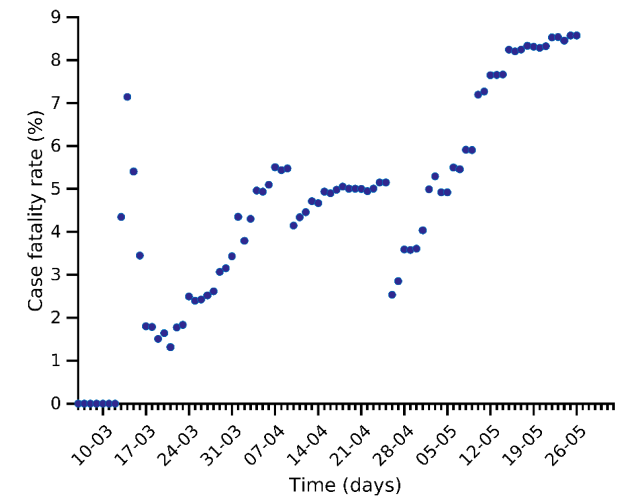



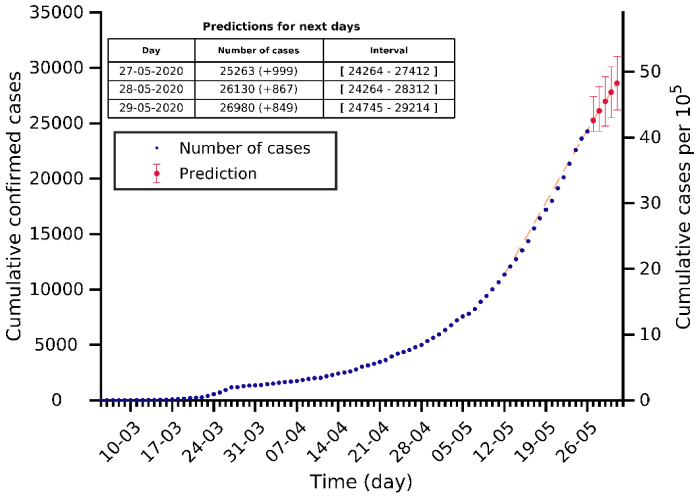



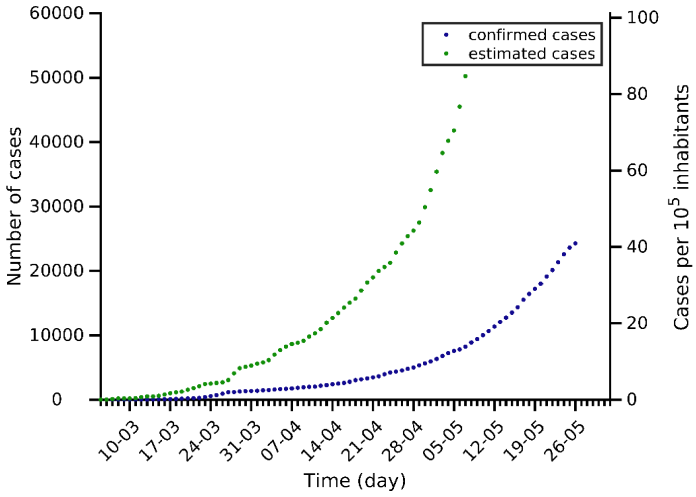



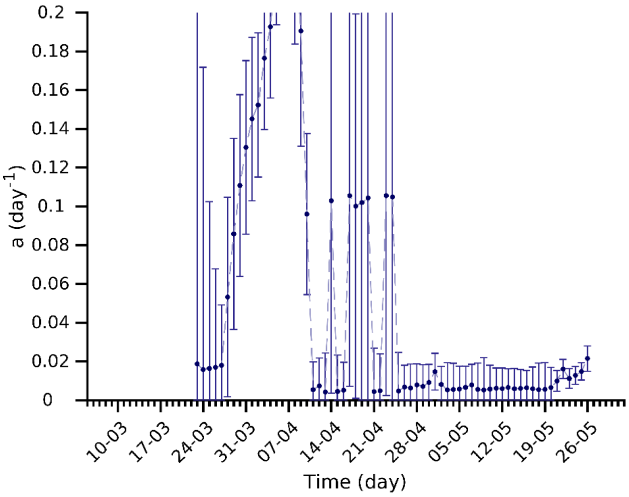



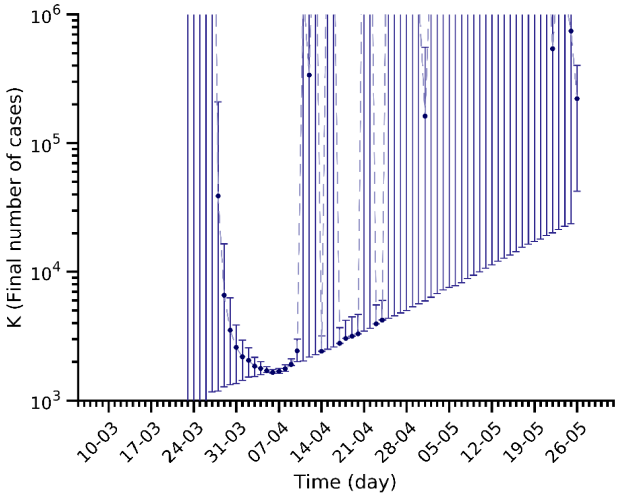



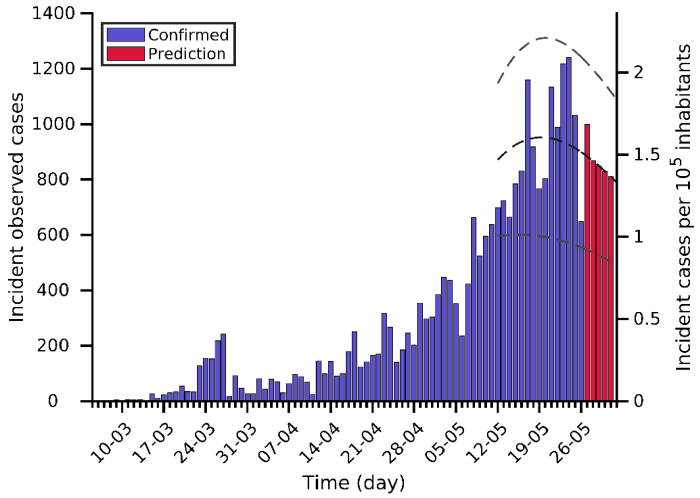
# South Africa 26-05-2020. Population: 59.3M. Current cumulated incidence: $41/10^5$

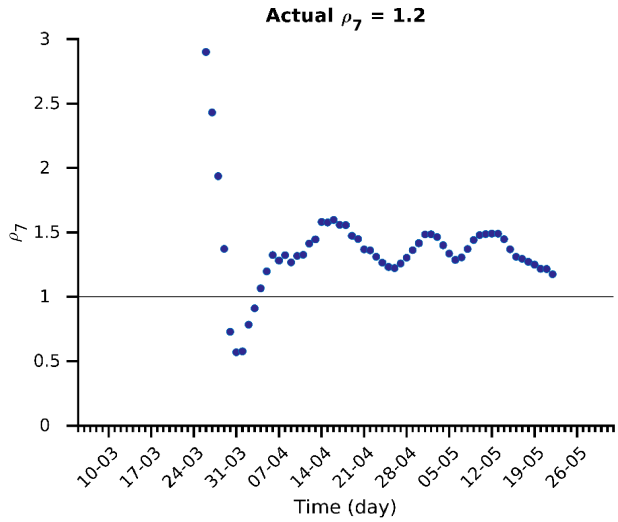


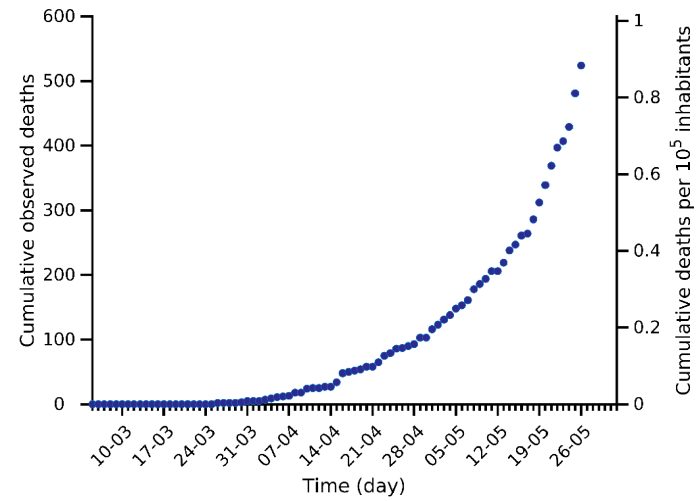



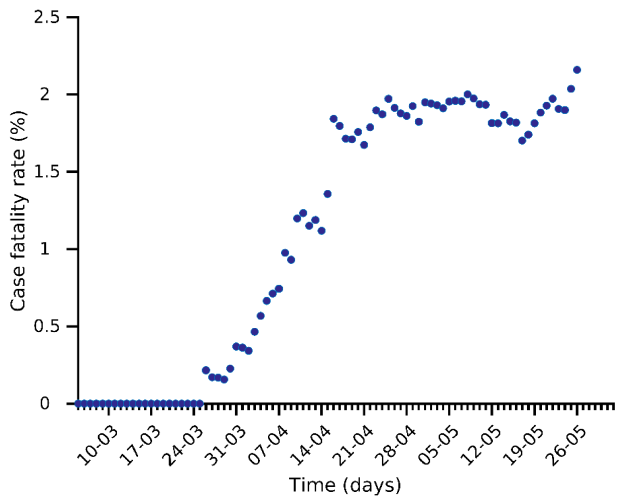



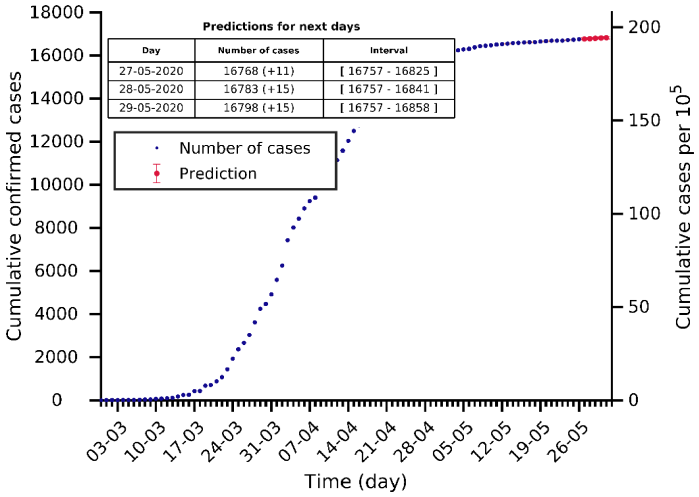



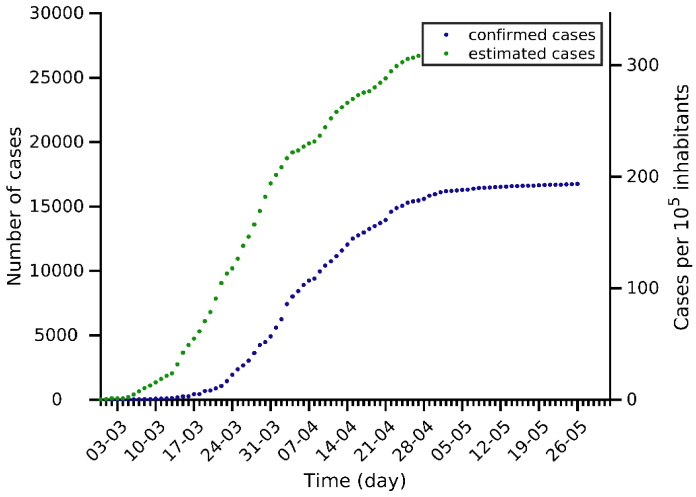



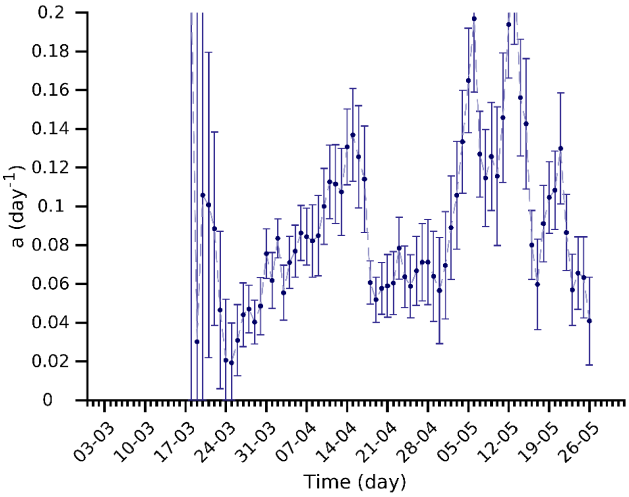



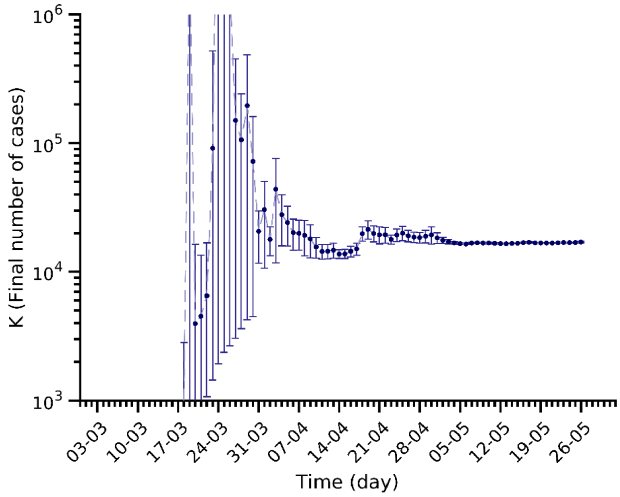



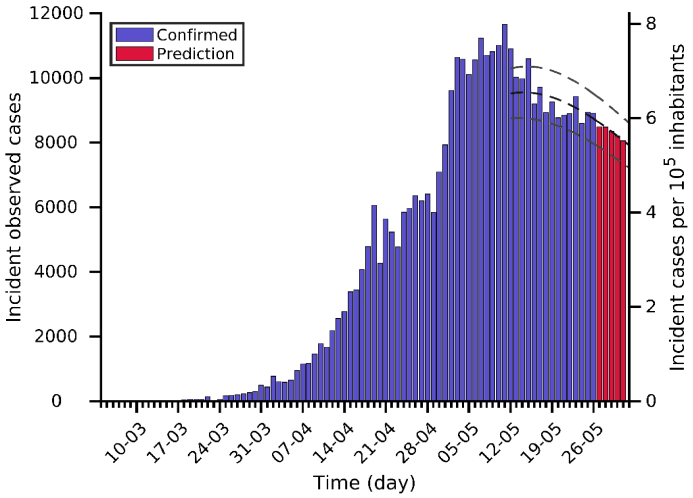
# Israel 26-05-2020. Population: 8.7M. Current cumulated incidence: 194/$10^5$

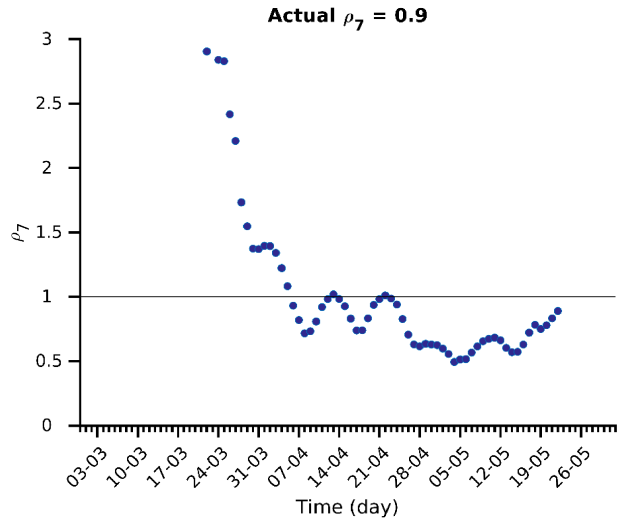


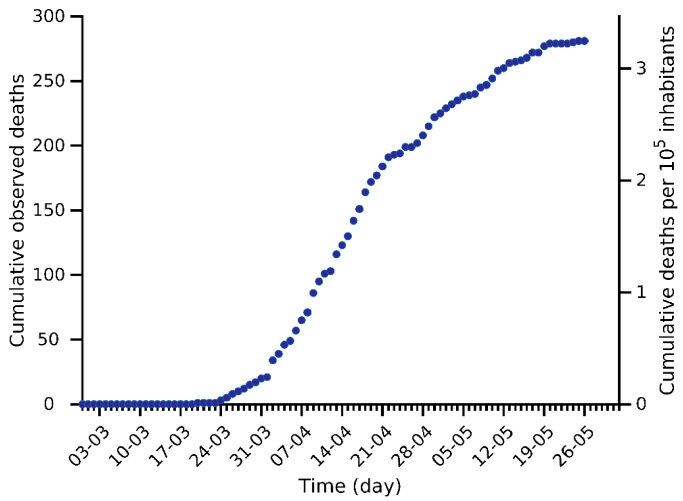



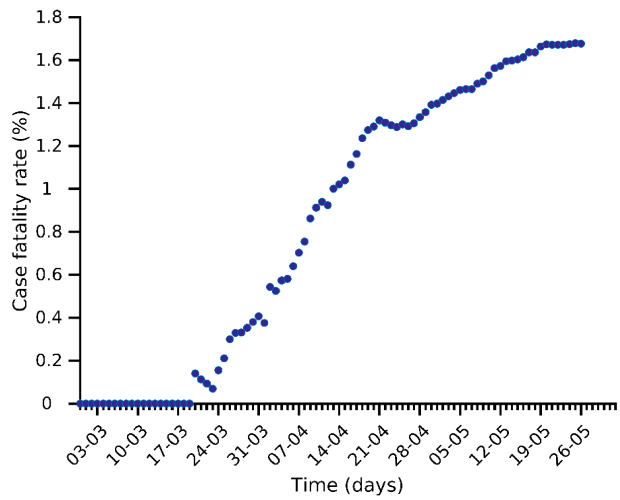



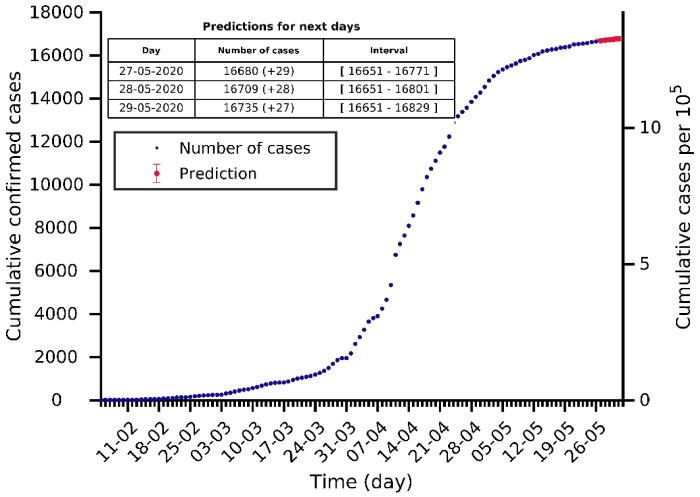



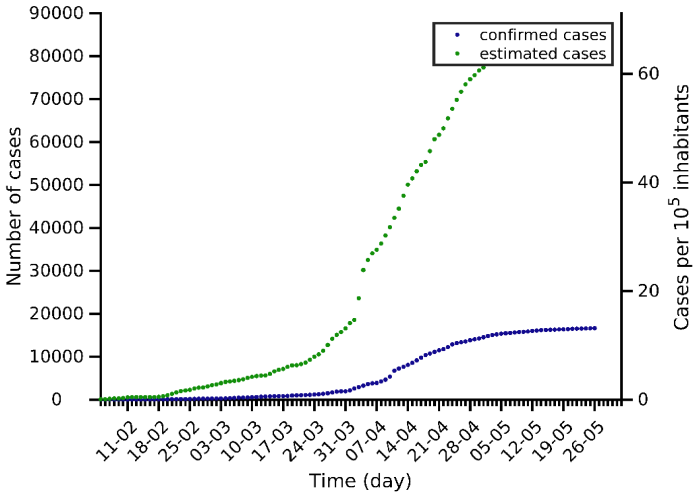



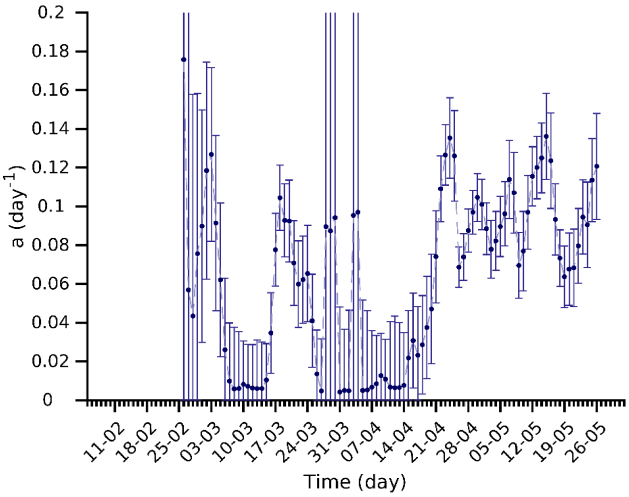



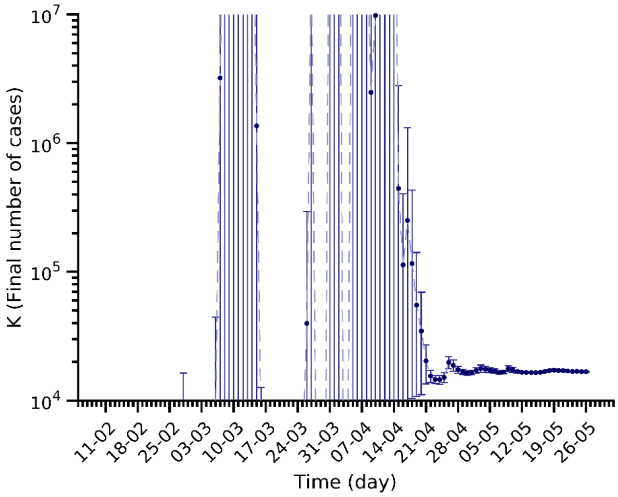



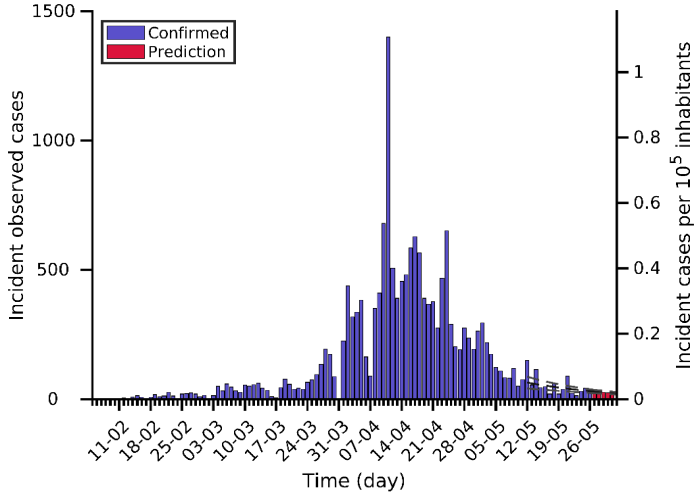
# Japan 26-05-2020. Population: 126.5M. Current cumulated incidence: 13/$10^5$

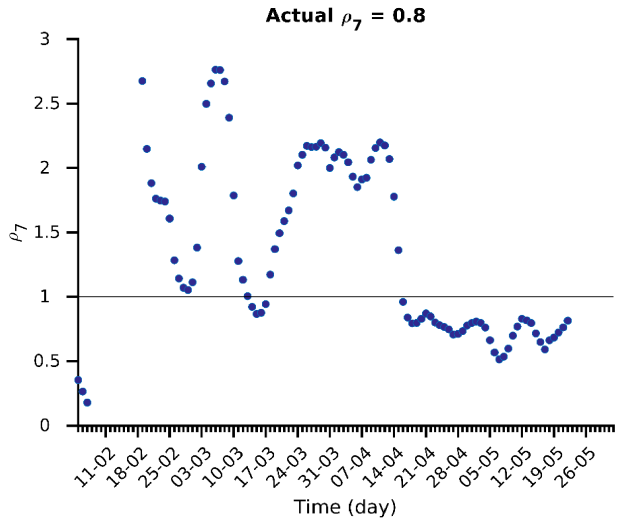


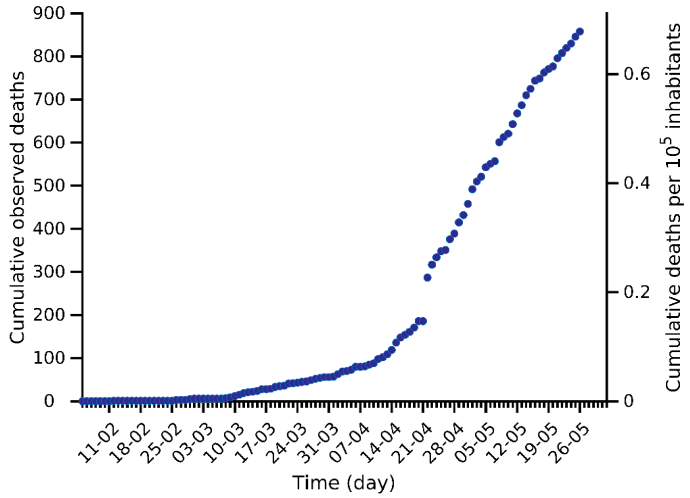



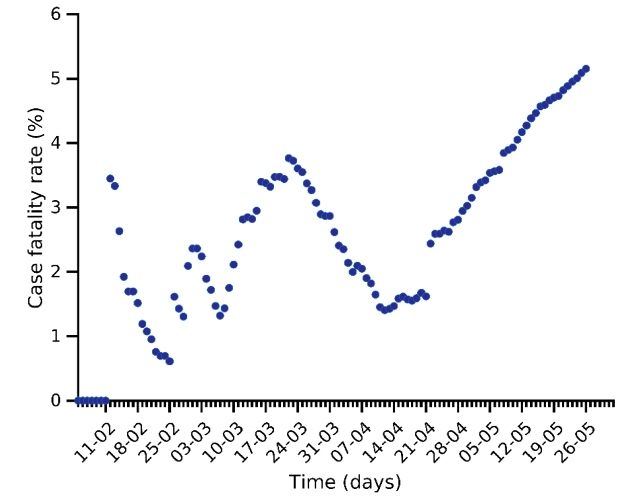



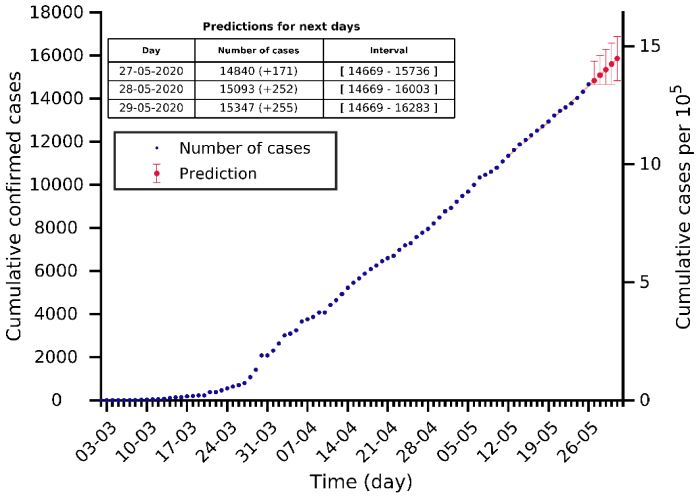



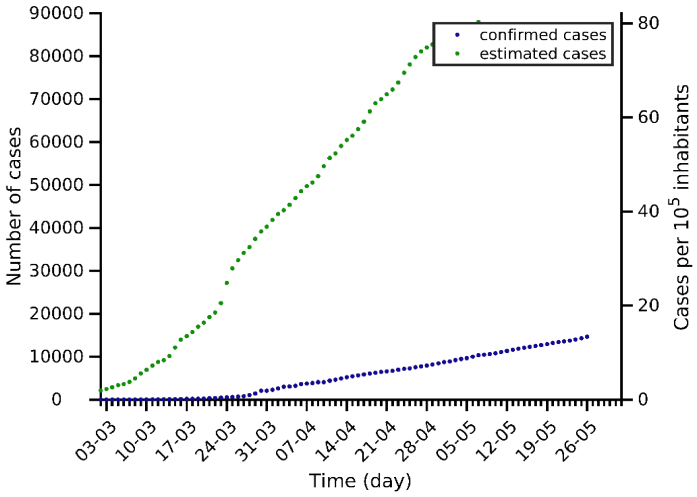



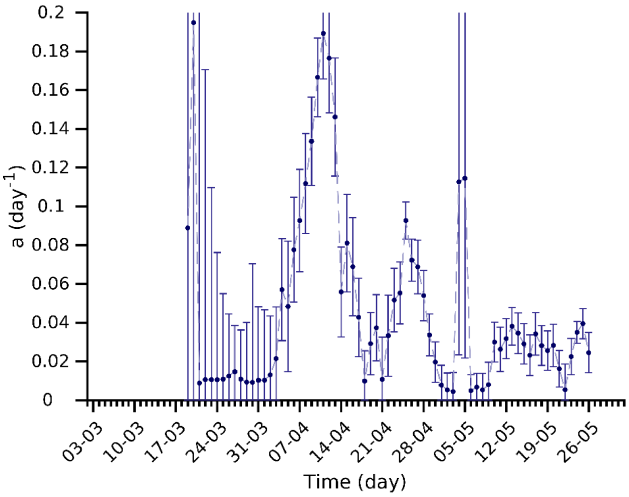



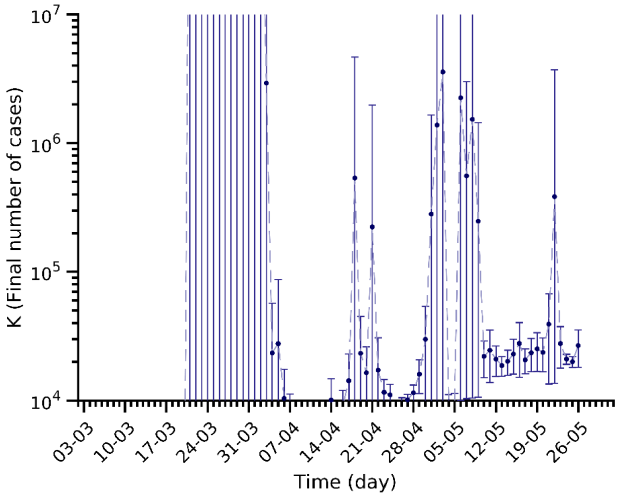



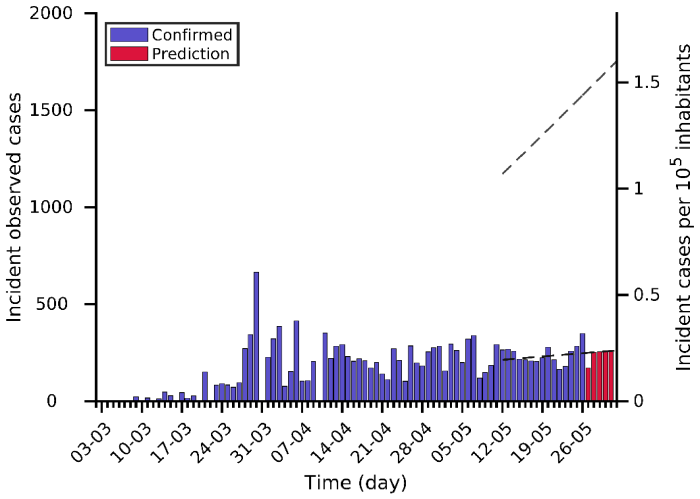
# Philippines 26-05-2020. Population: 109.6M. Current cumulated incidence: 13/$10^5$

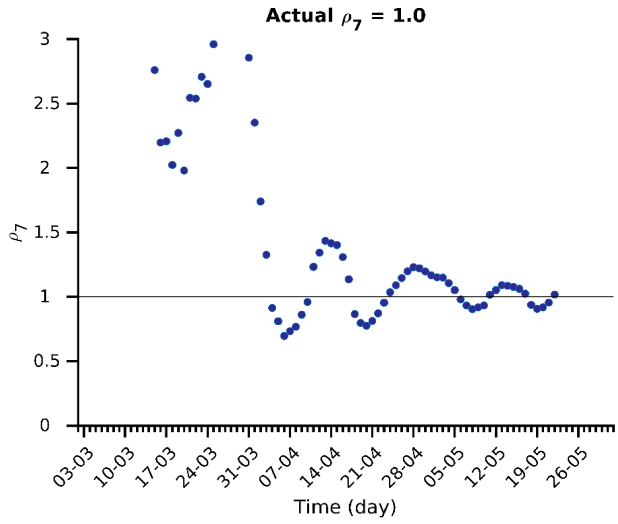


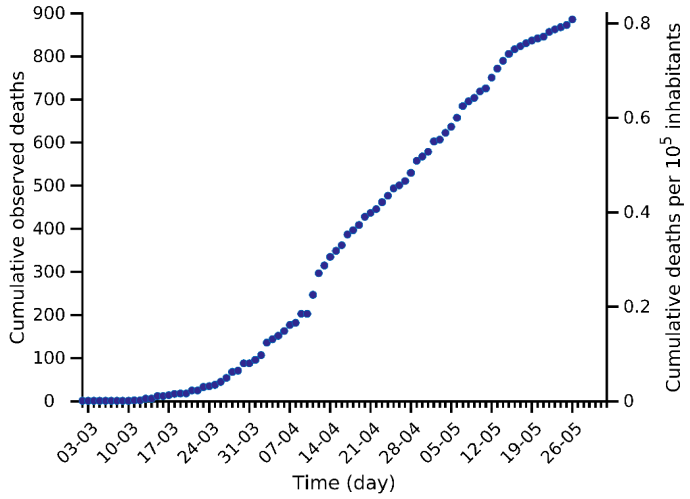



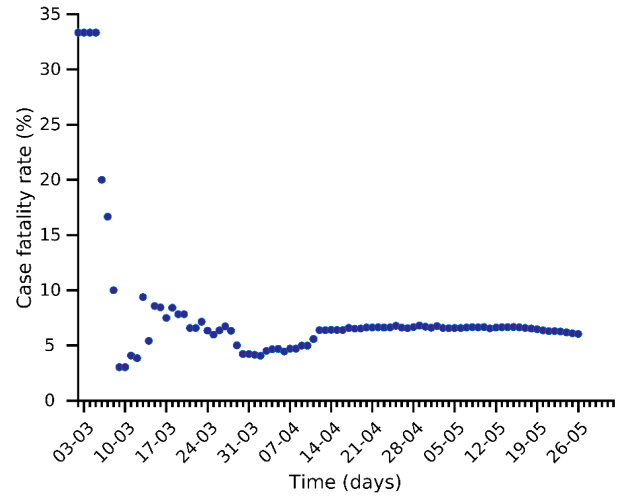



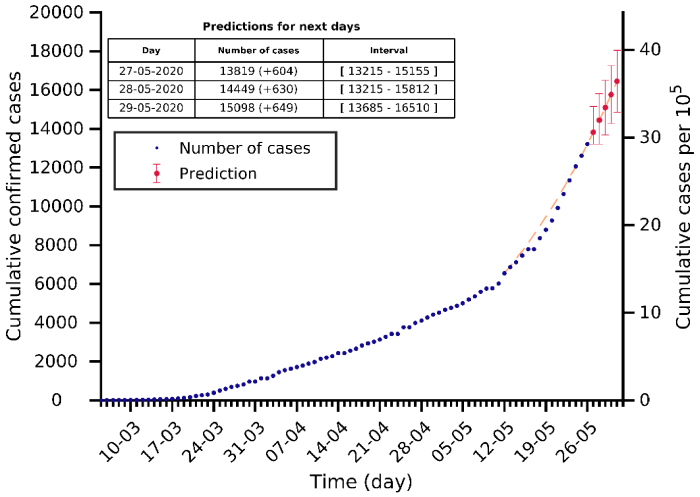



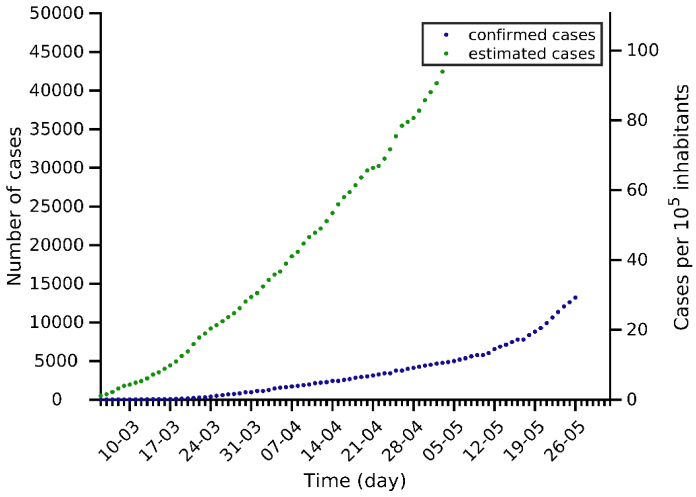



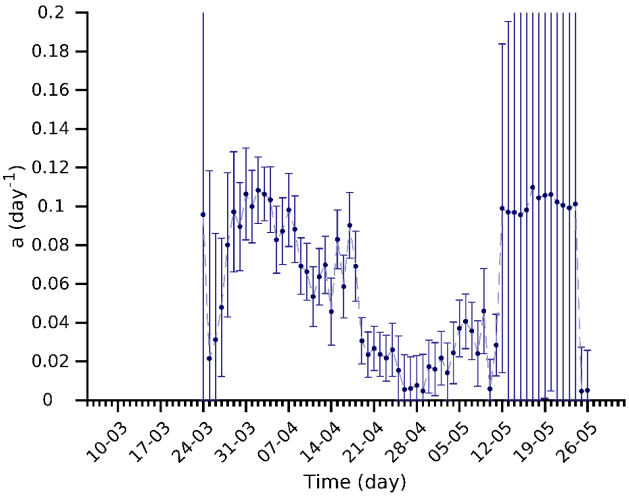



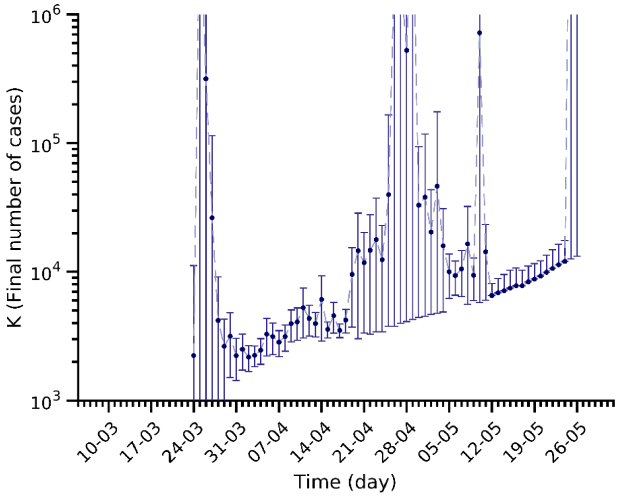



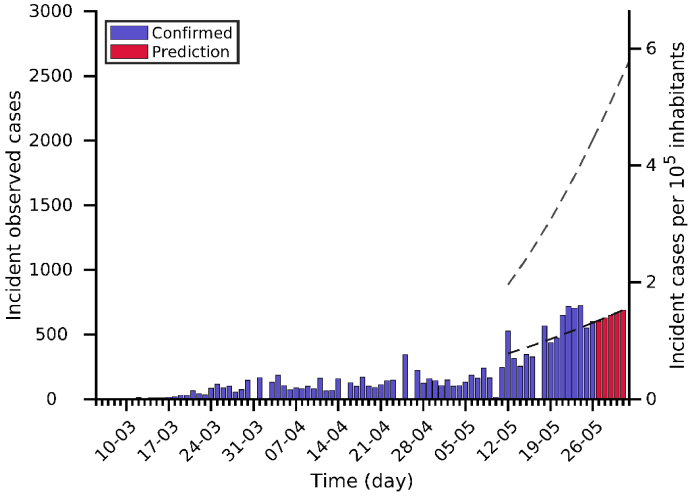
# Argentina  26-05-2020. Population: 45.2M. Current cumulated incidence: 29/$10^5$

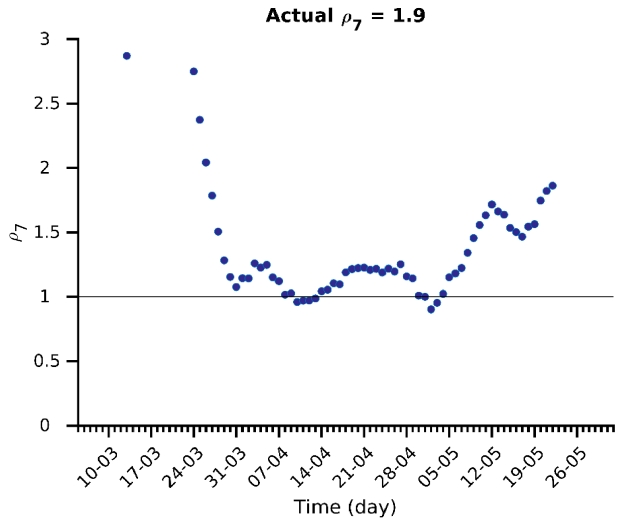


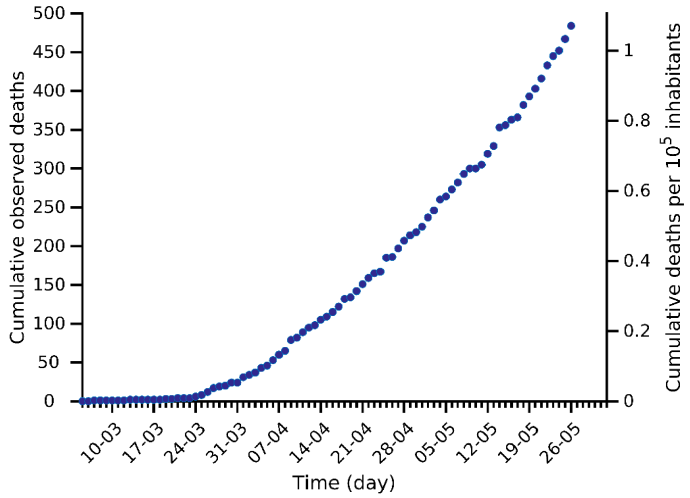



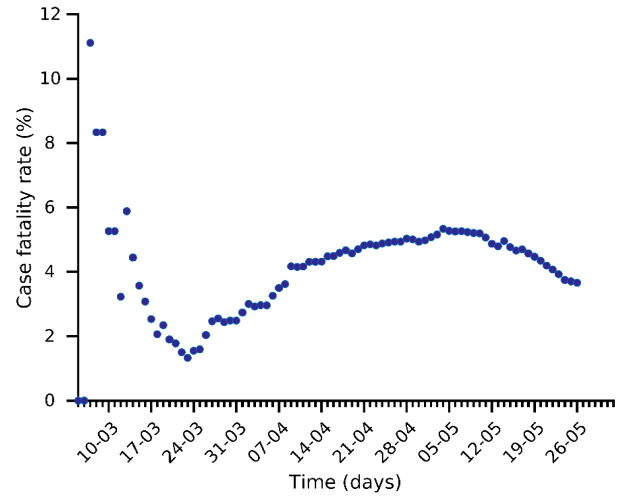



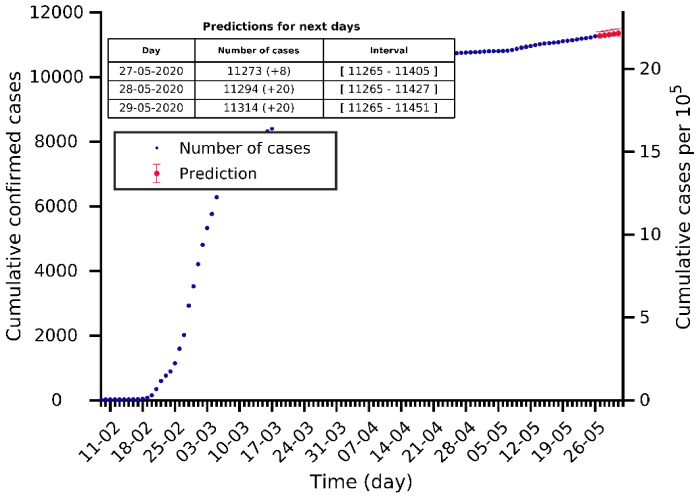



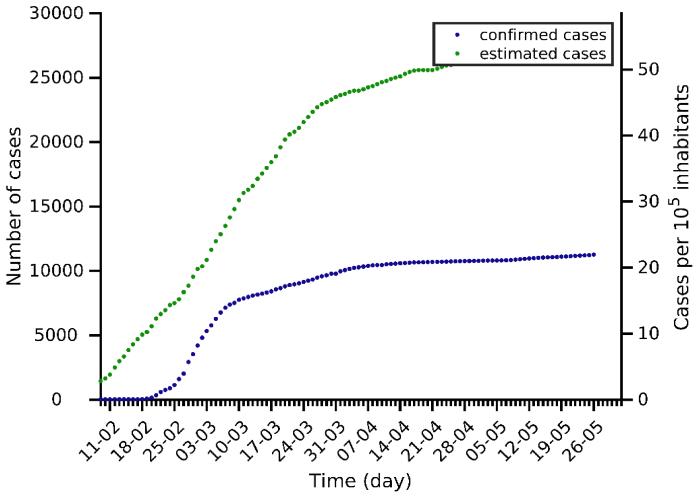



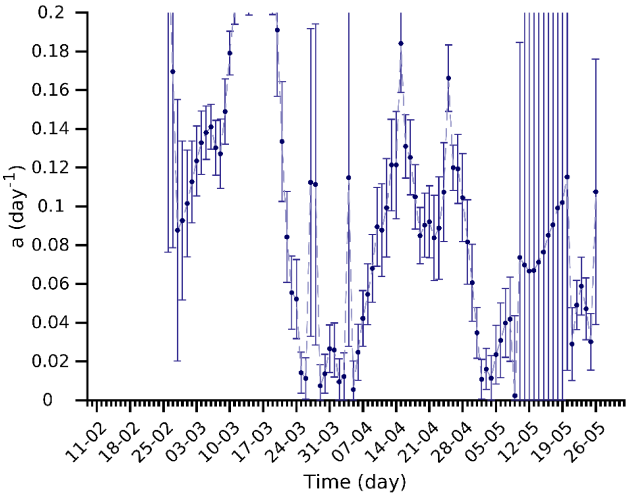



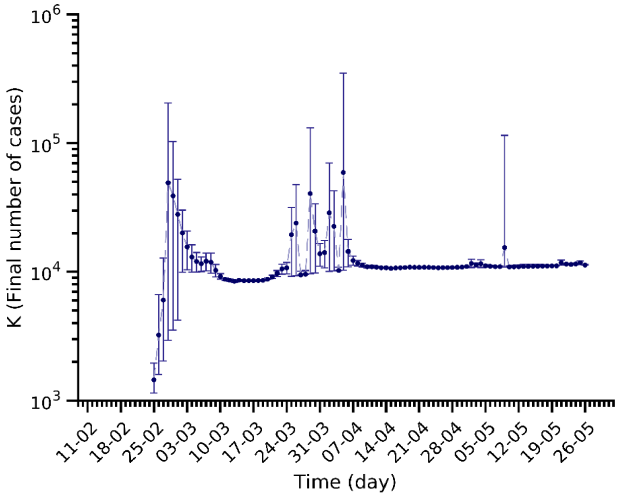



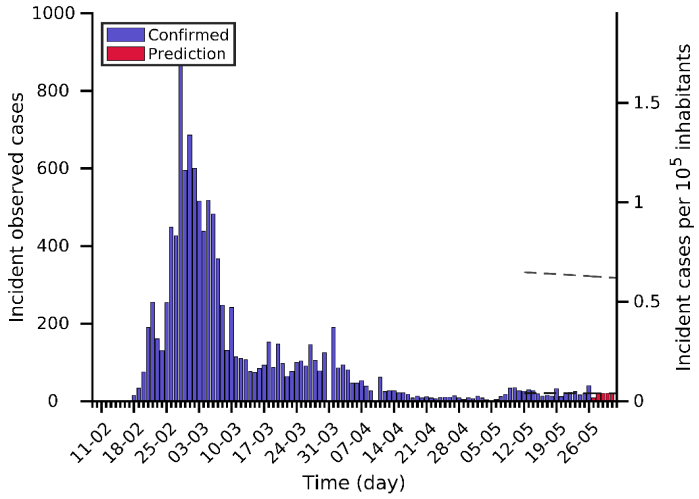
# South Korea  26-05-2020. Population: 51.3M. Current cumulated incidence: $22/10^5$

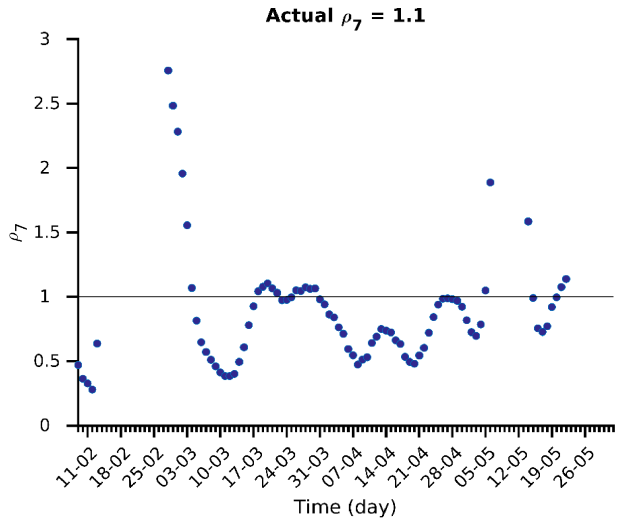


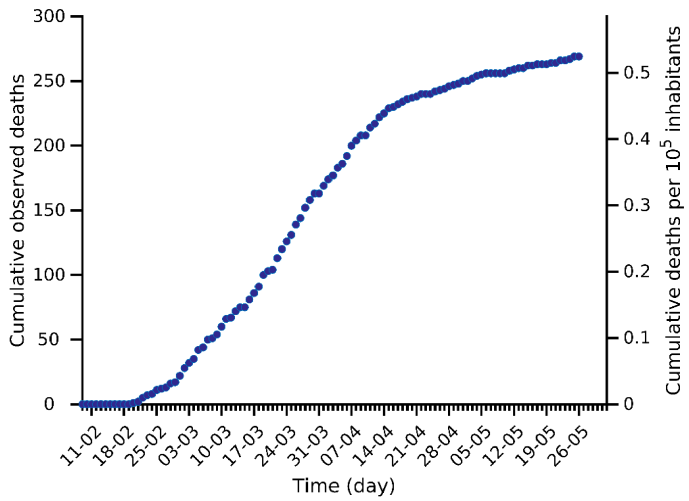



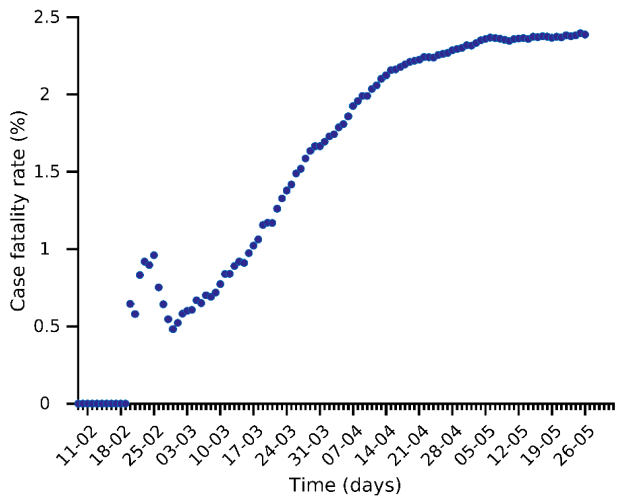



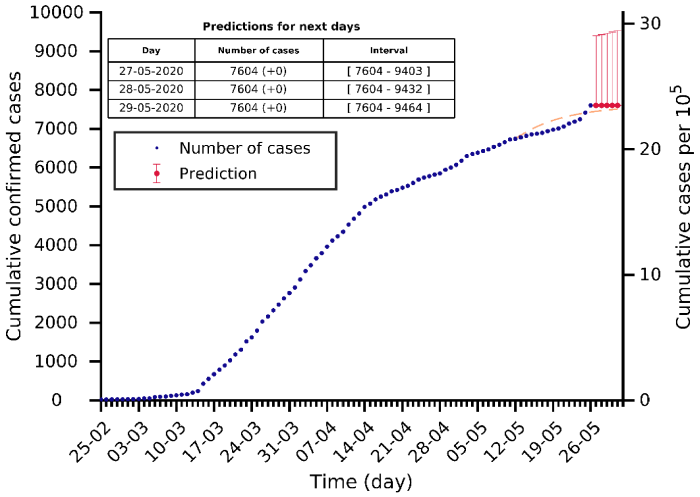



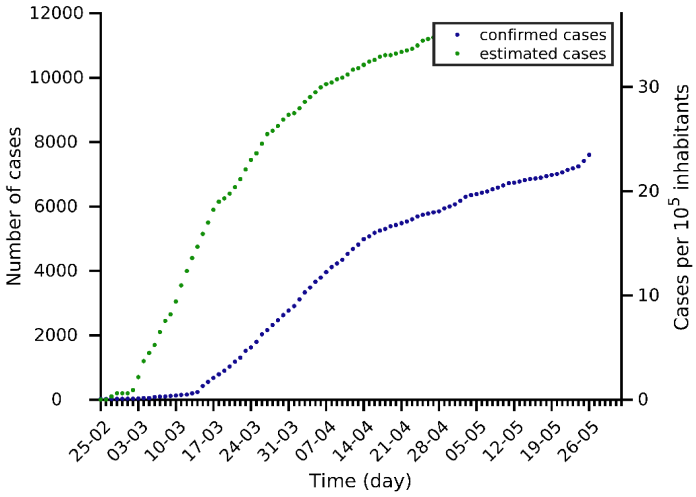



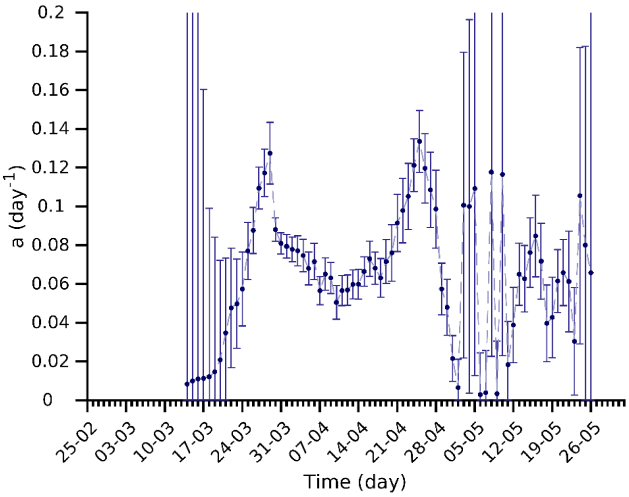



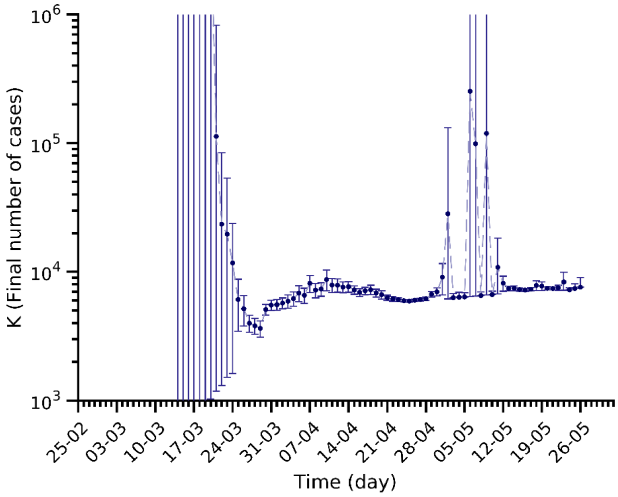



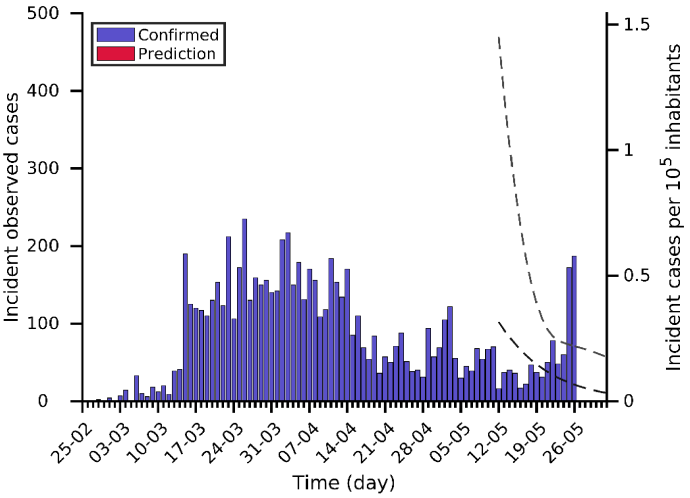
# Malaysia 26-05-2020. Population: 32.4M. Current cumulated incidence: $23/10^5$

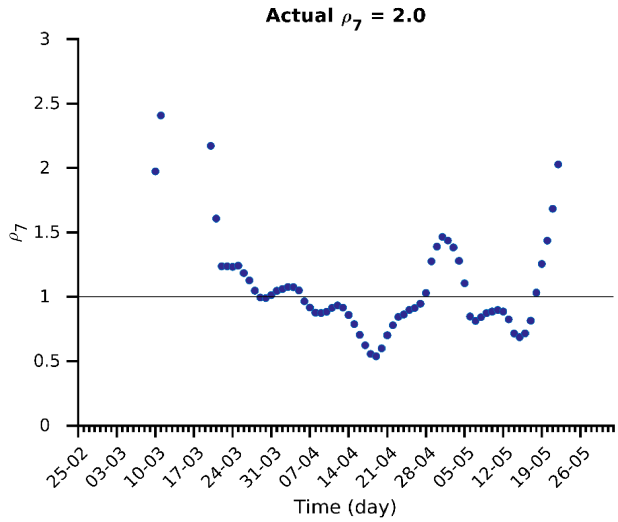


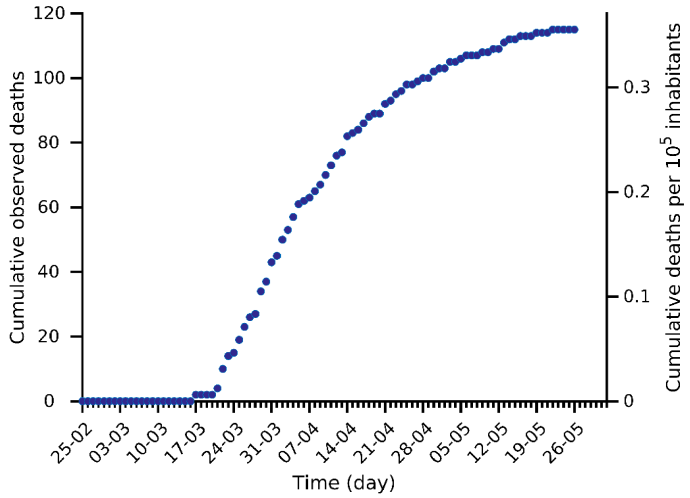



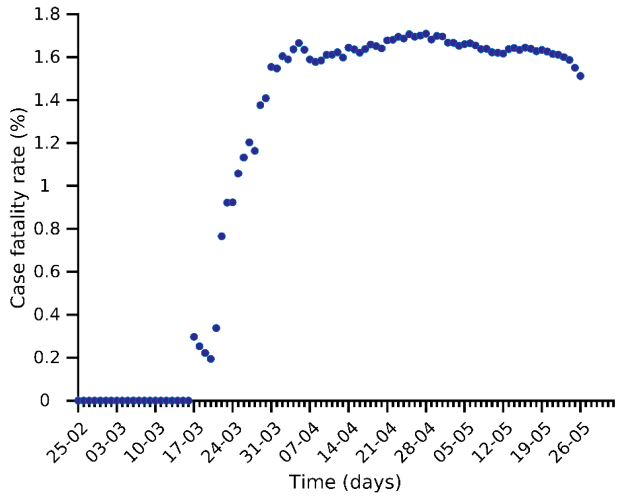



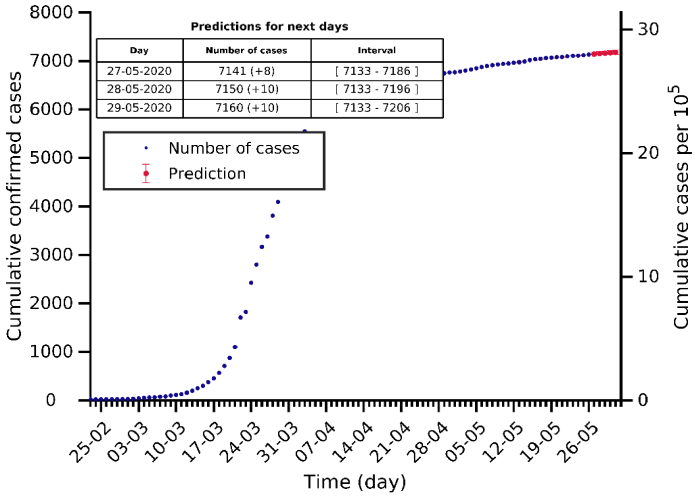



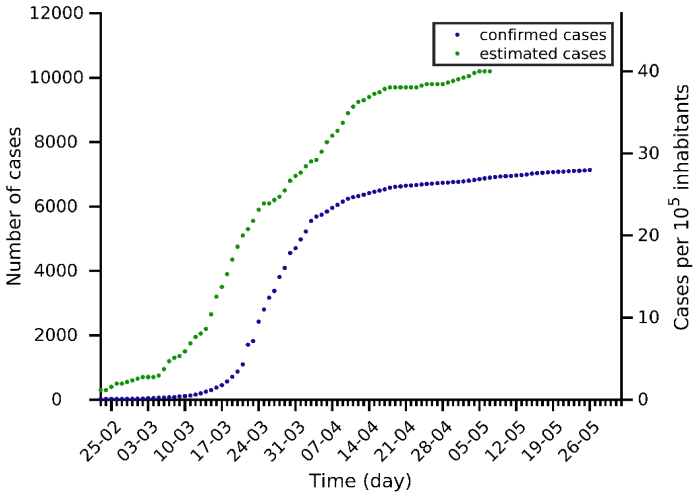



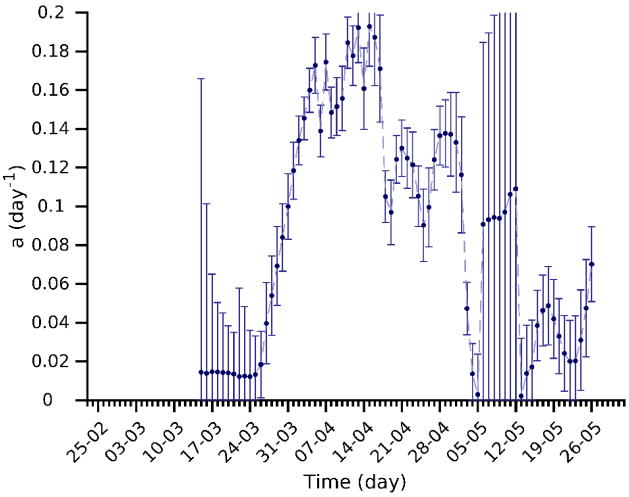



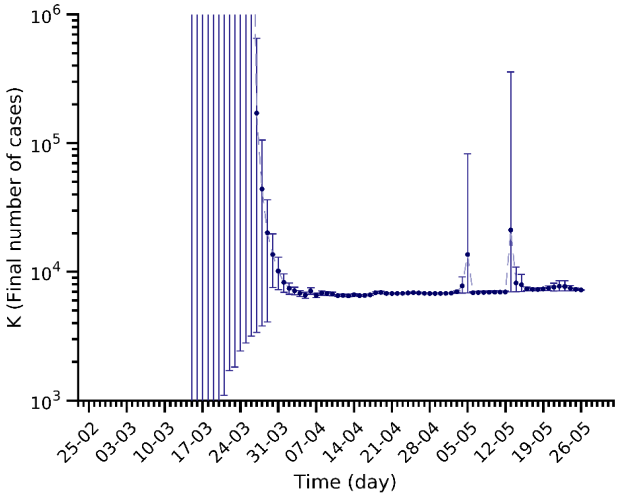



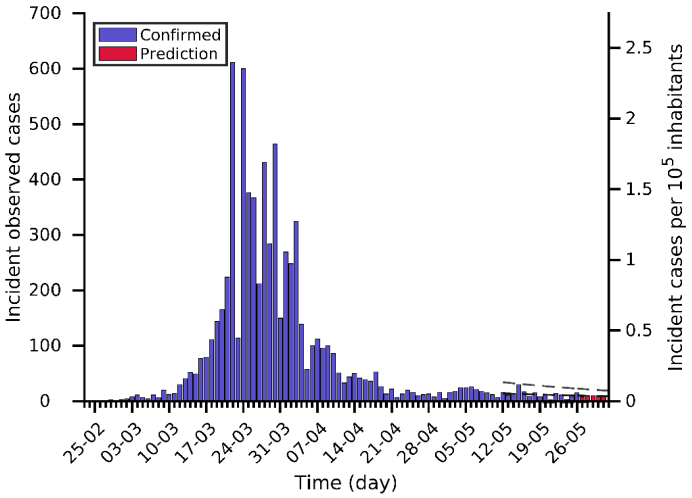
# Australia 26-05-2020. Population: 25.5M. Current cumulated incidence: $28/10^5$

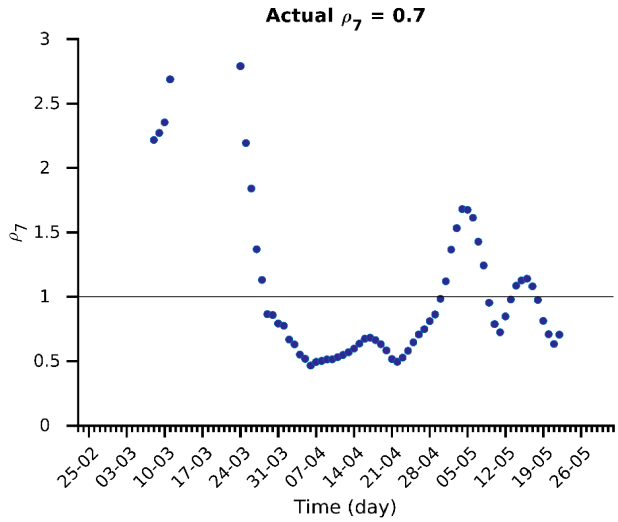


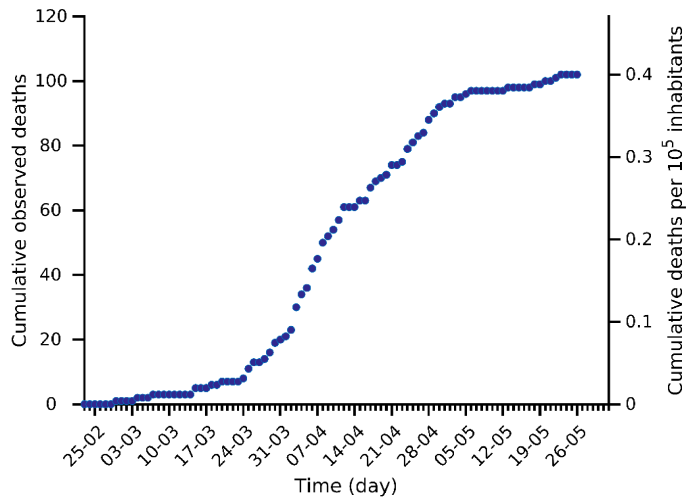



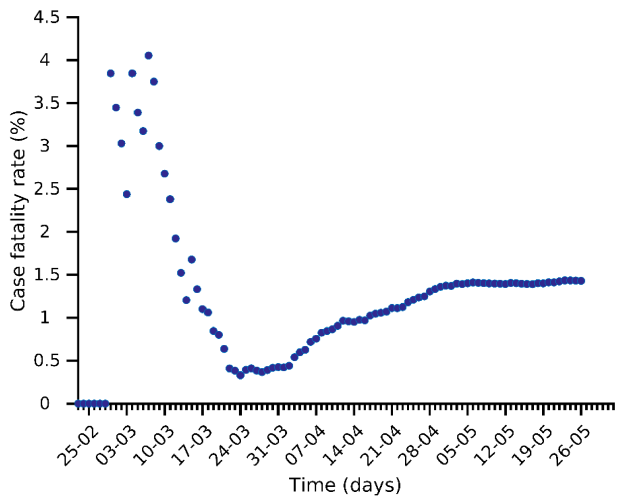



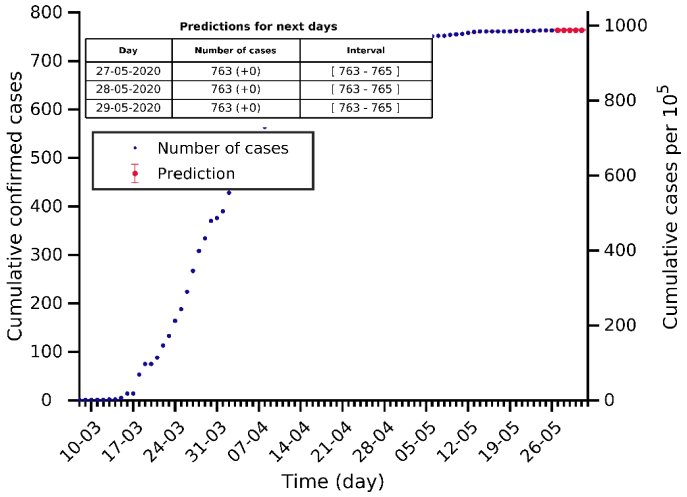



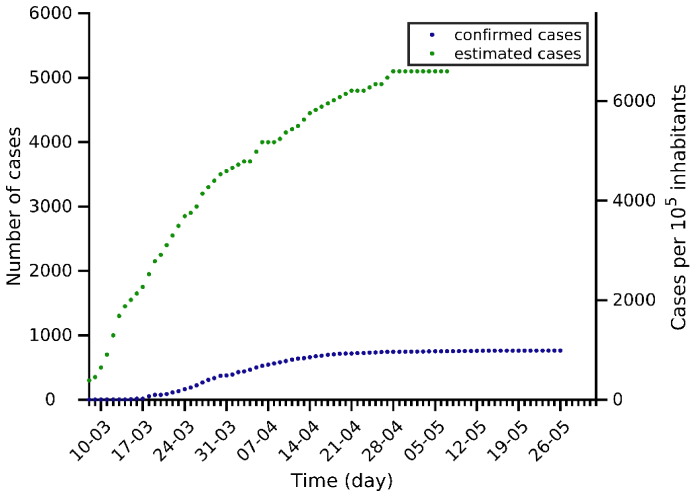



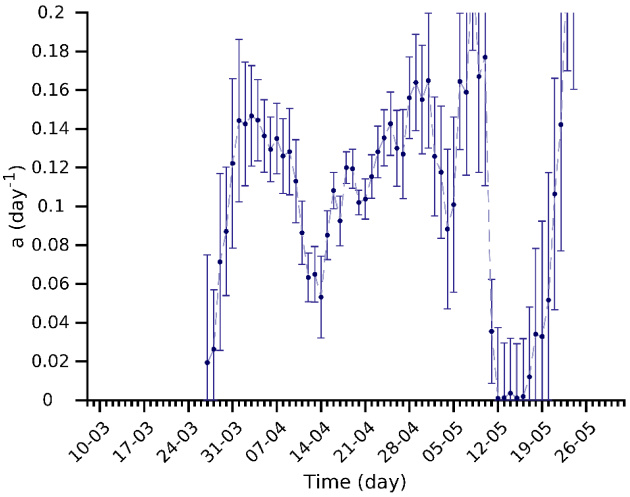



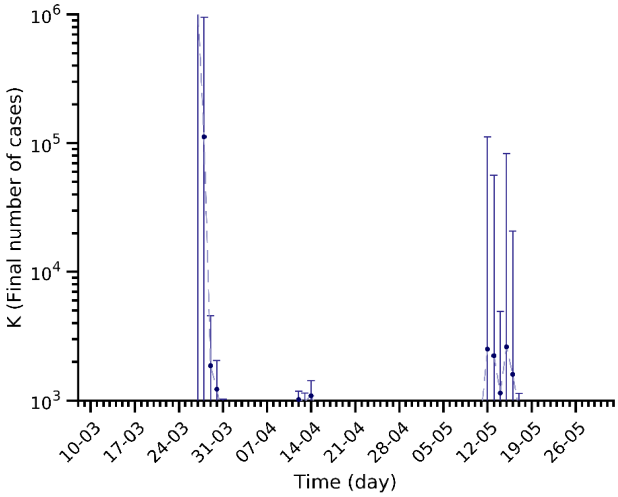



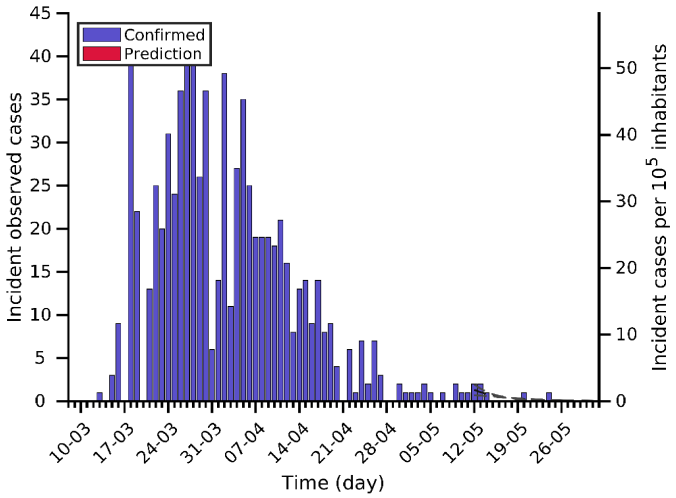
# Andorra 26-05-2020. Population: 0.1M. Current cumulated incidence: 988/$10^5$

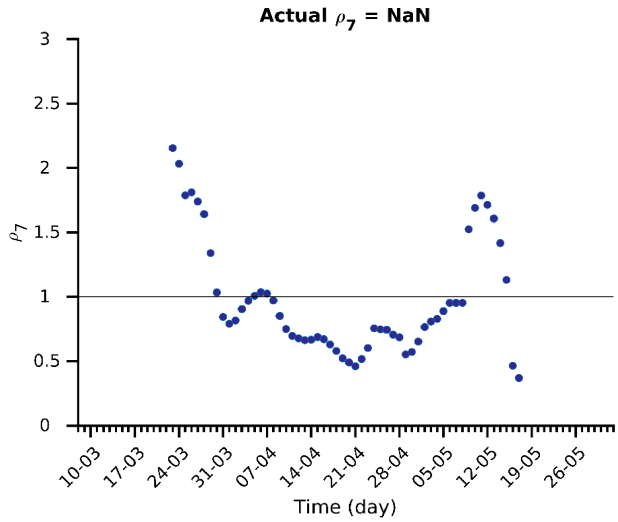


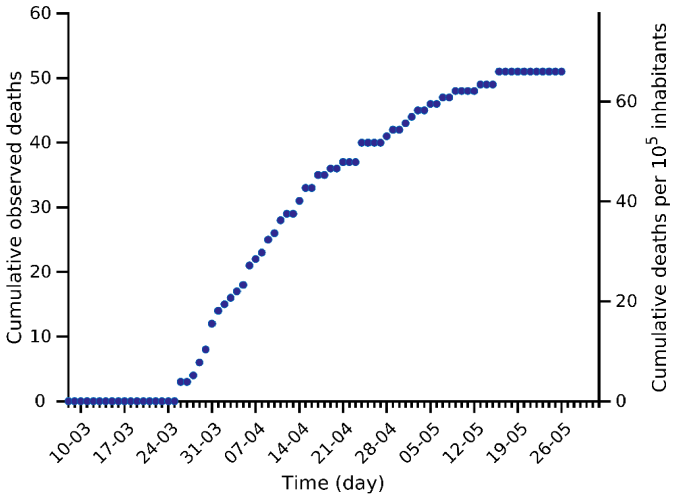



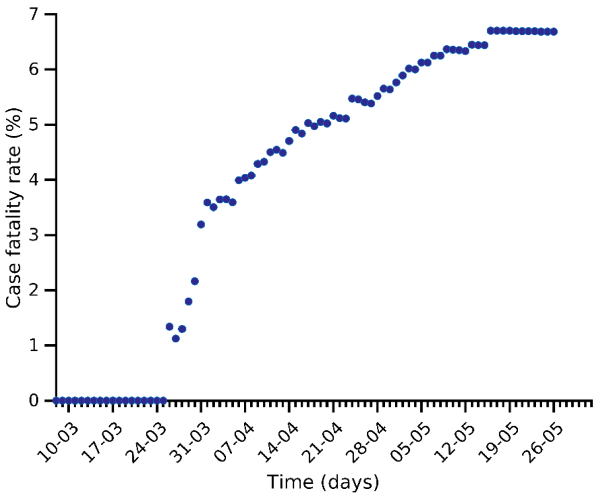



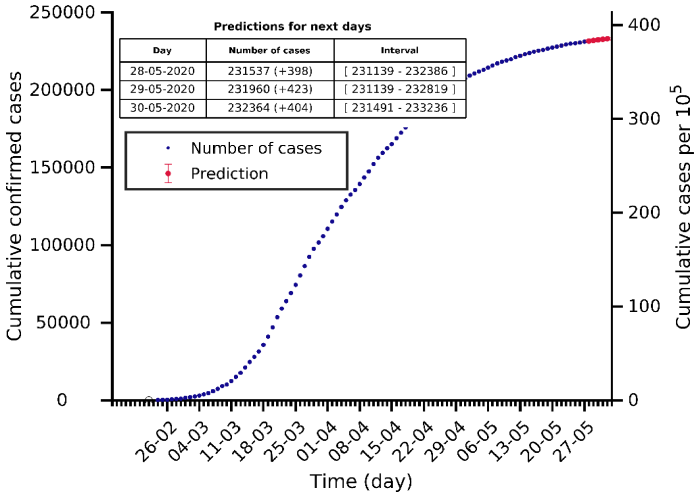



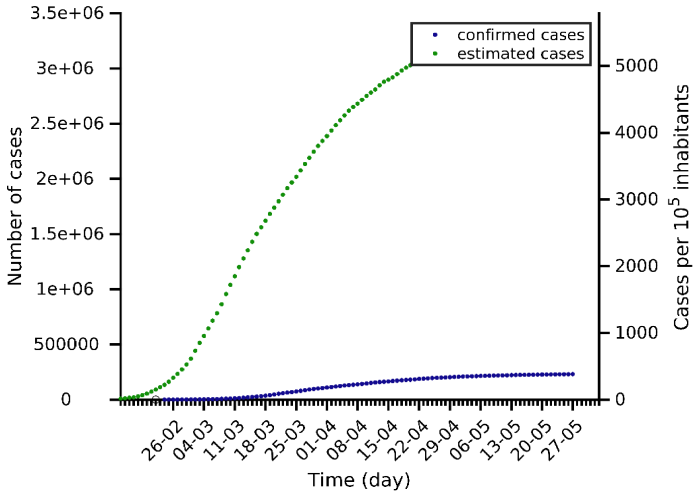



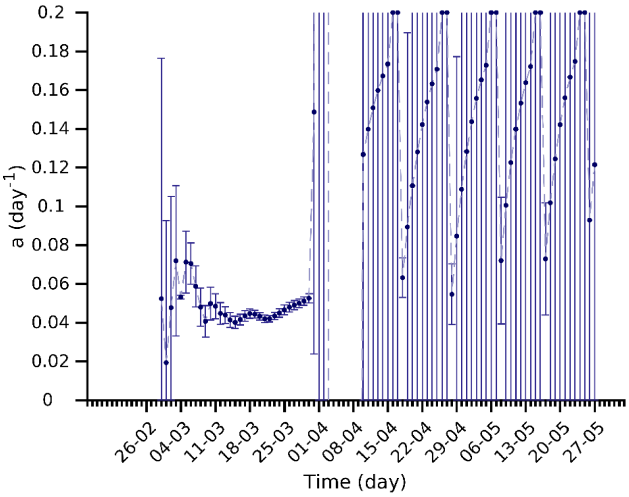
# (3) Analysis and prediction of COVID-19 for Italy and its regions

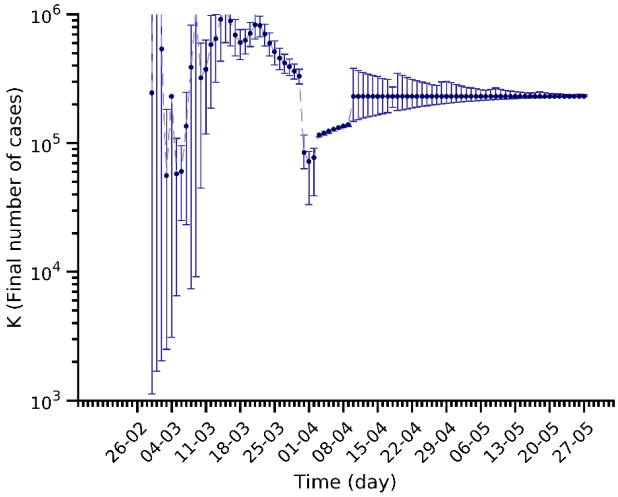
Data obtained from: https://github.com/pcm-dpc/COVID-19/tree/master/dati-andamento-nazionale

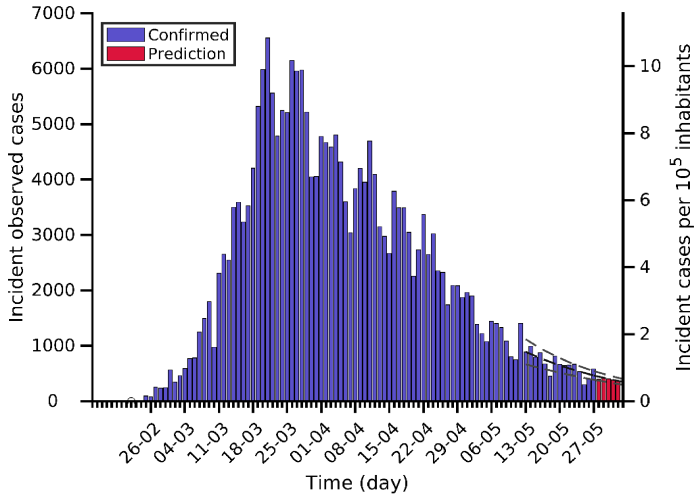
# Italy 27-05-2020. Population: 60.5M. Current cumulated incidence: 382/$10^5$

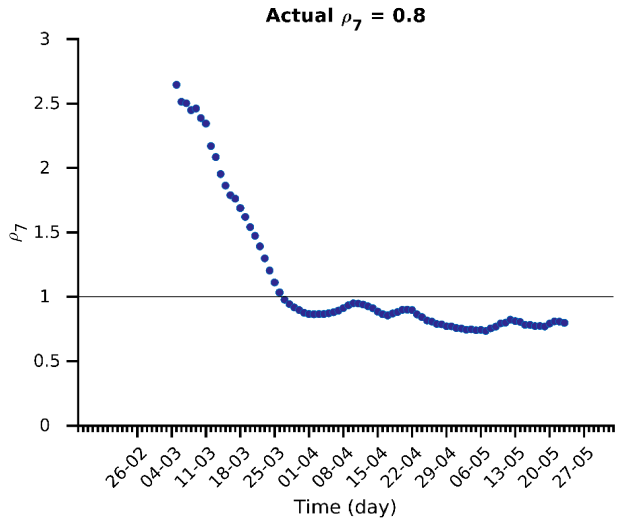


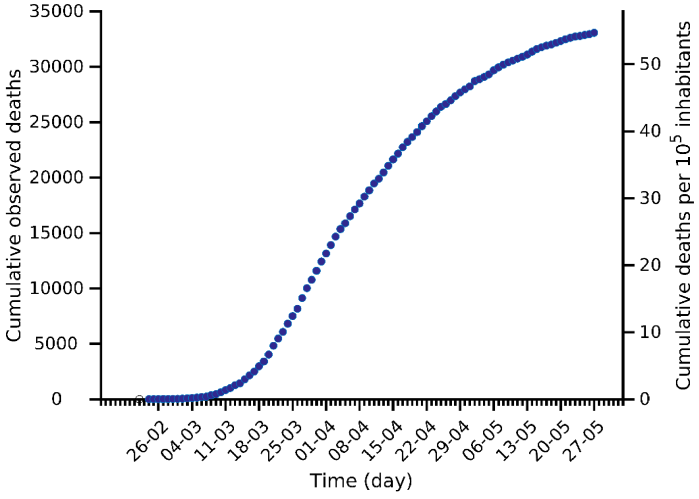



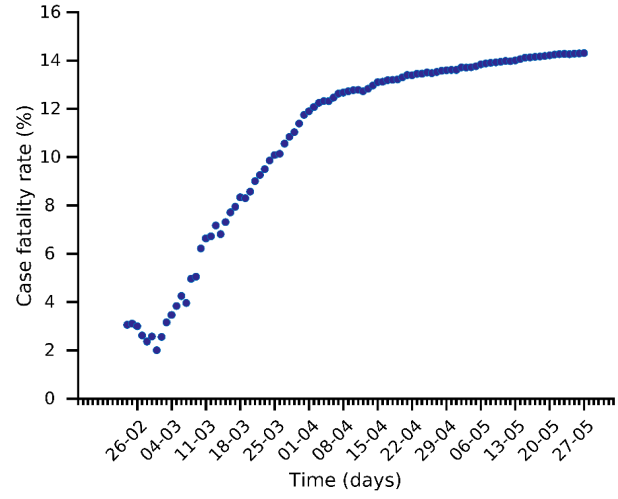



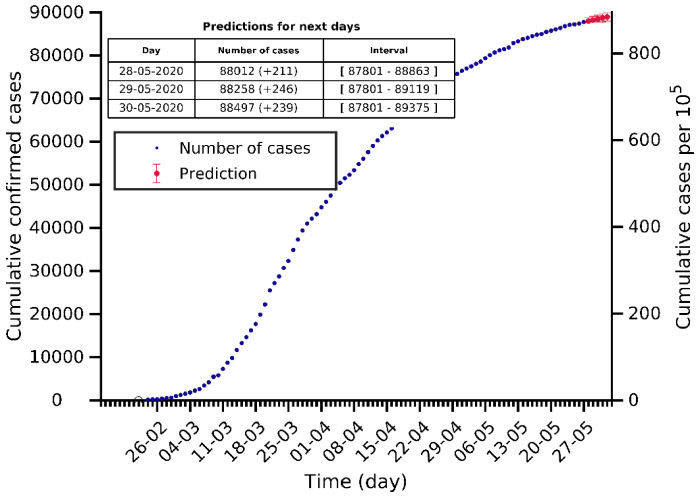



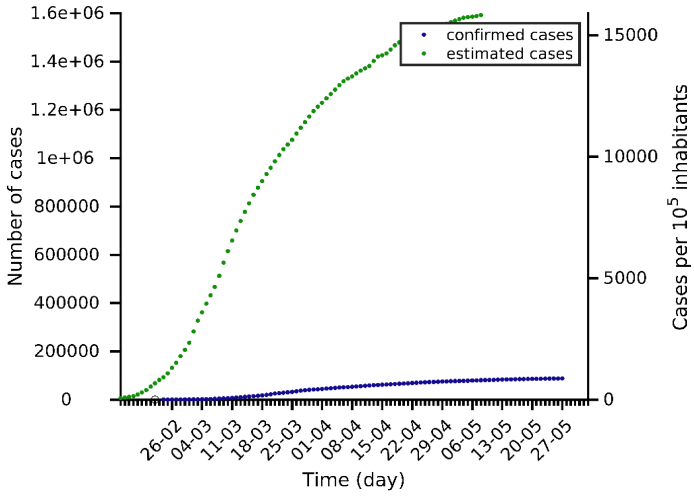



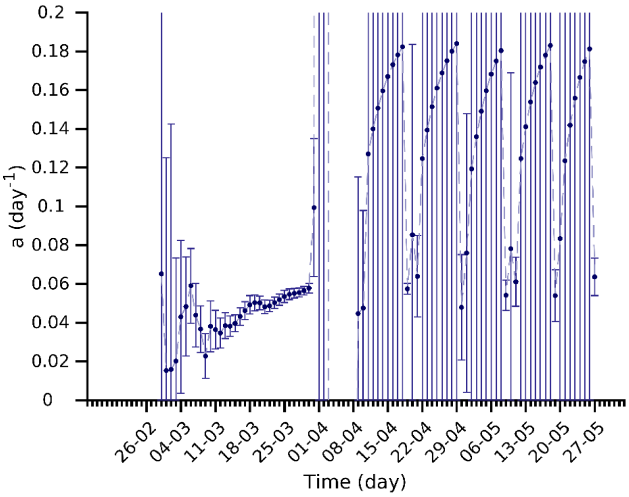



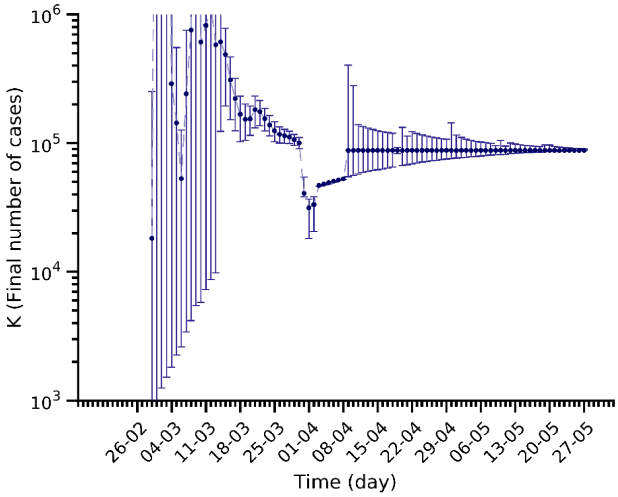



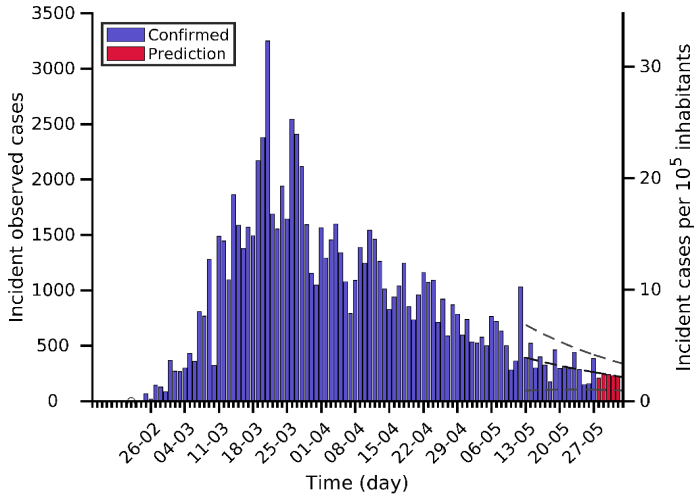
# Lombardia 27-05-2020. Population: 10.1M. Current cumulated incidence: 873/$10^5$

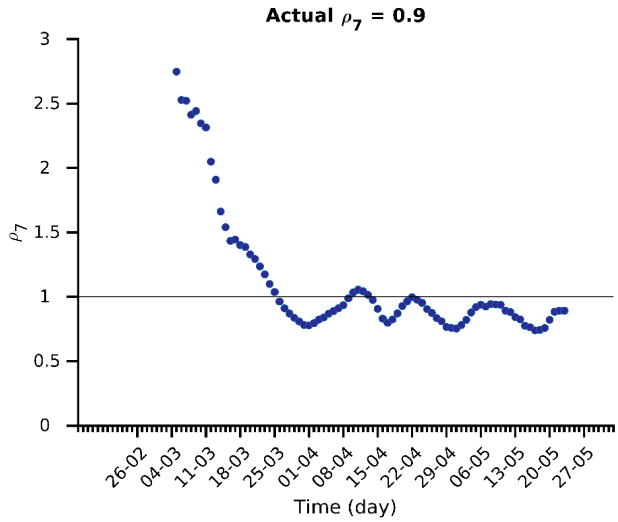


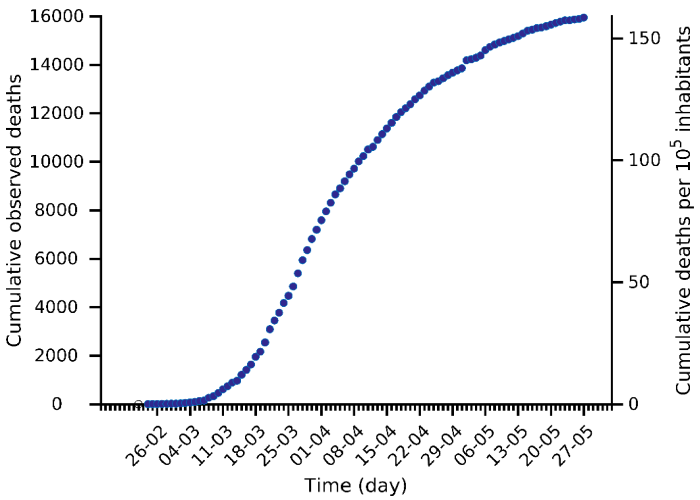



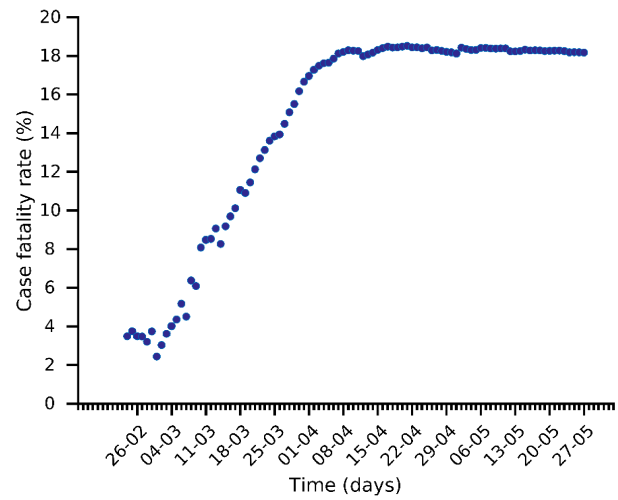



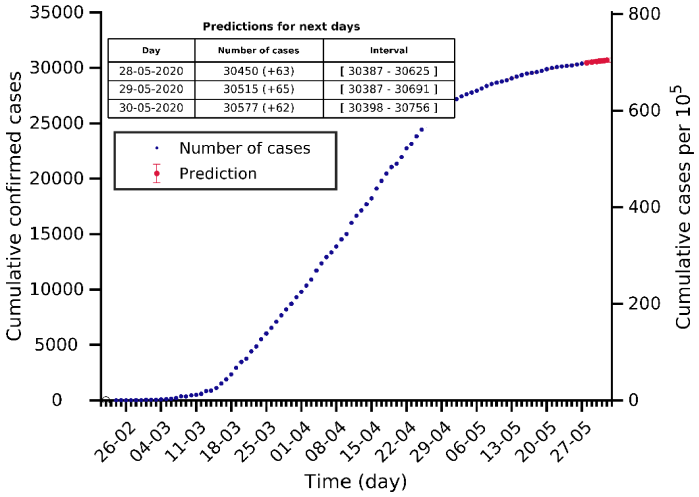



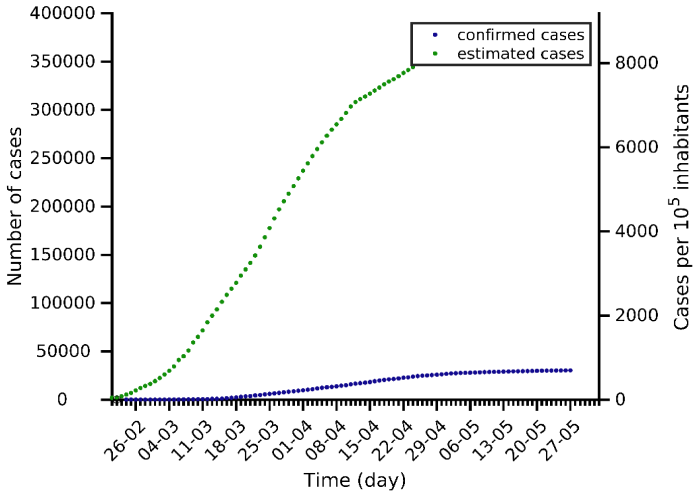



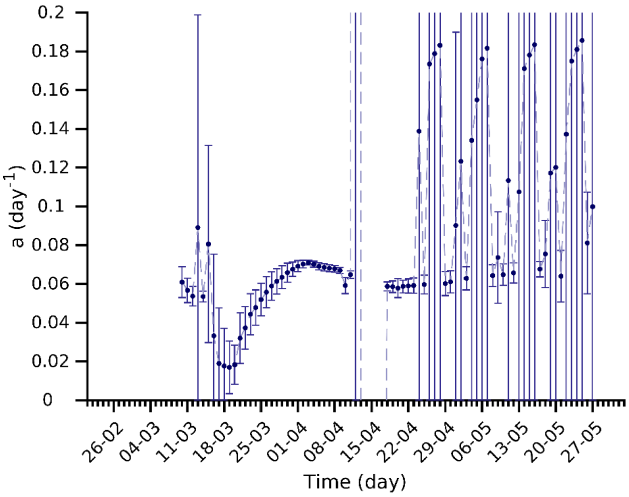



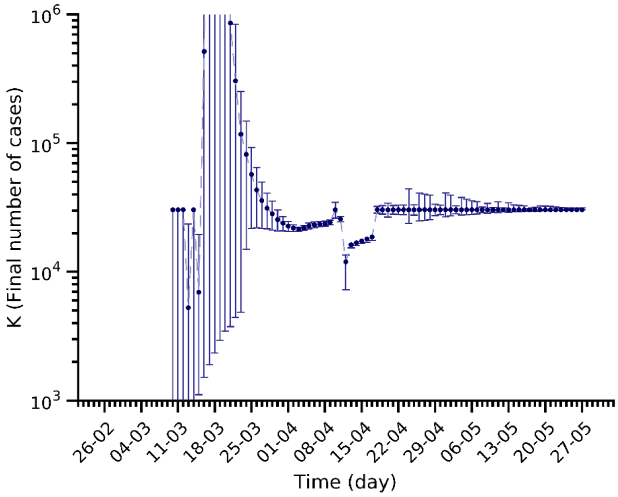



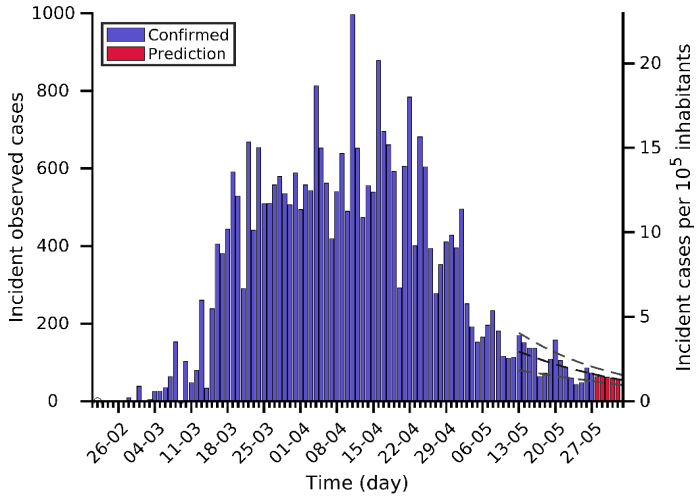
# Piemonte 27-05-2020. Population: 4.4M. Current cumulated incidence: 698/10⁵

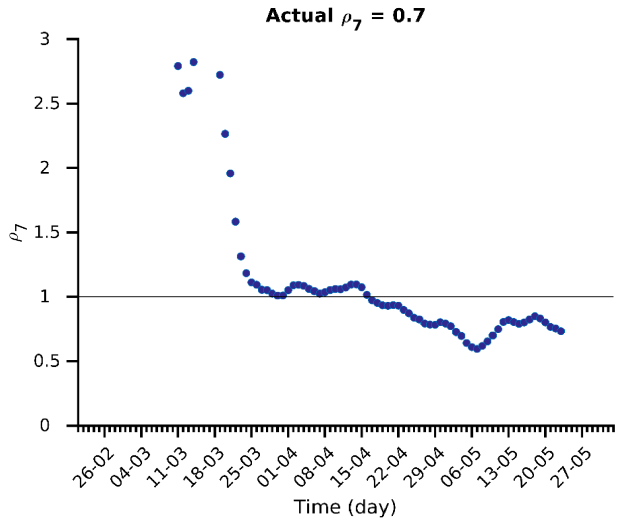


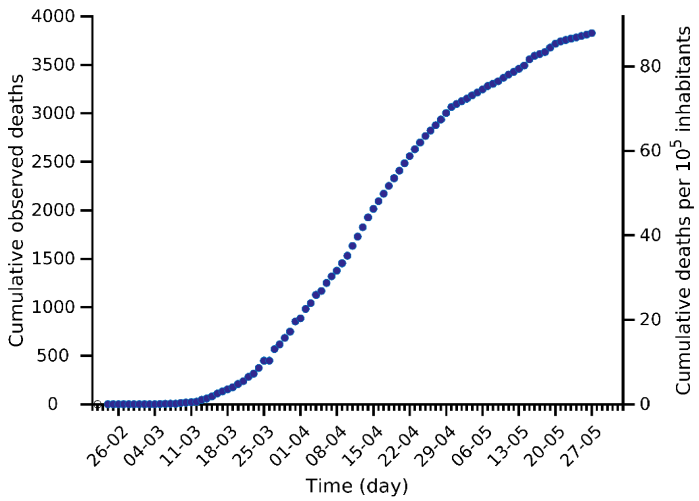



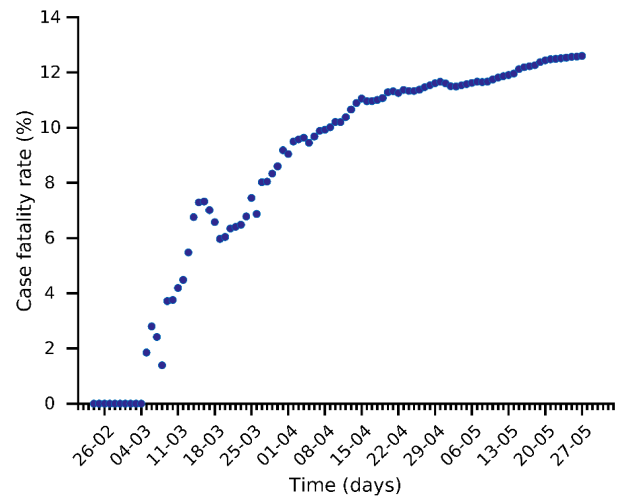



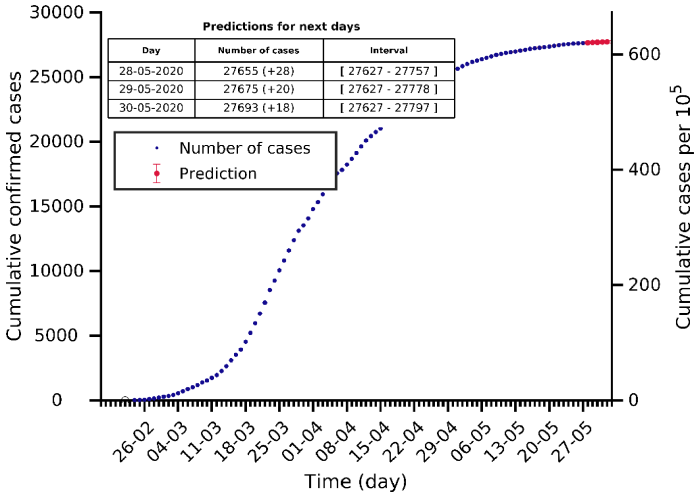



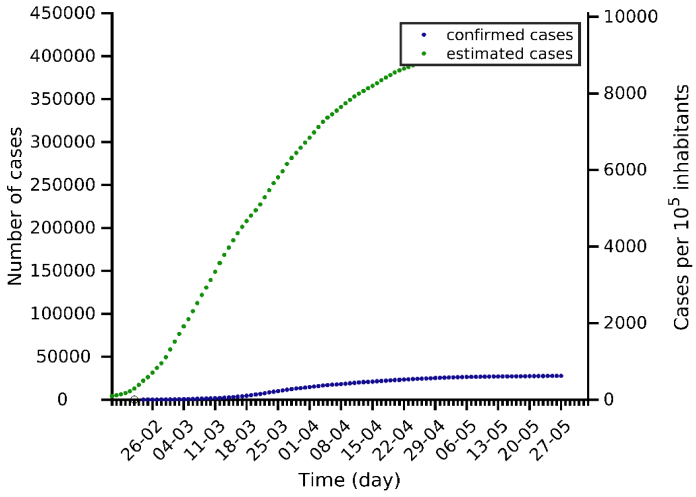



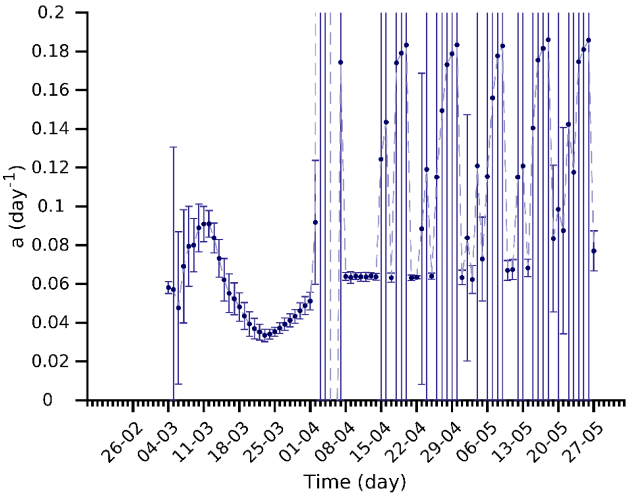



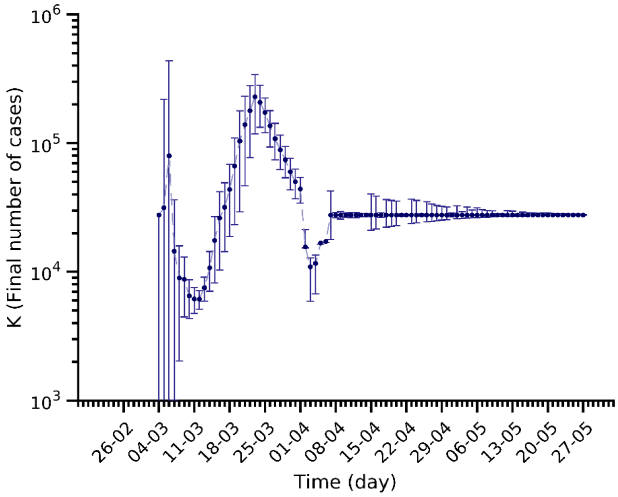



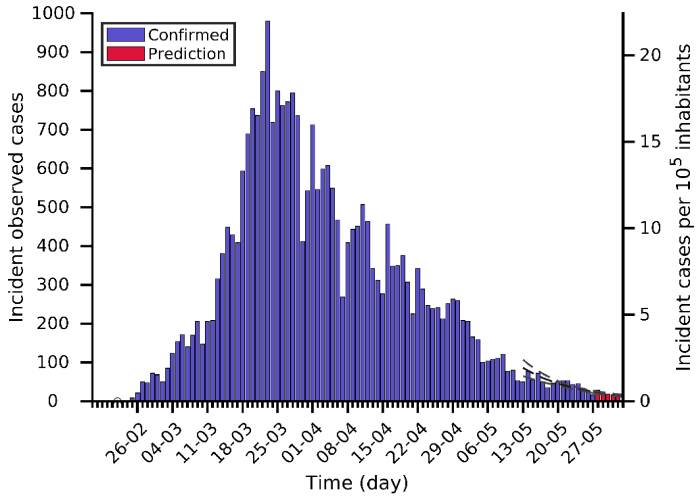
# Emilia Romagna  27-05-2020. Population: 4.5M. Current cumulated incidence: 620/1

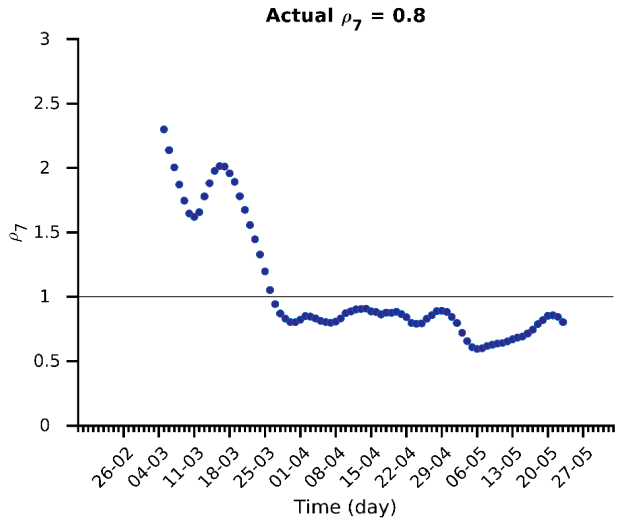


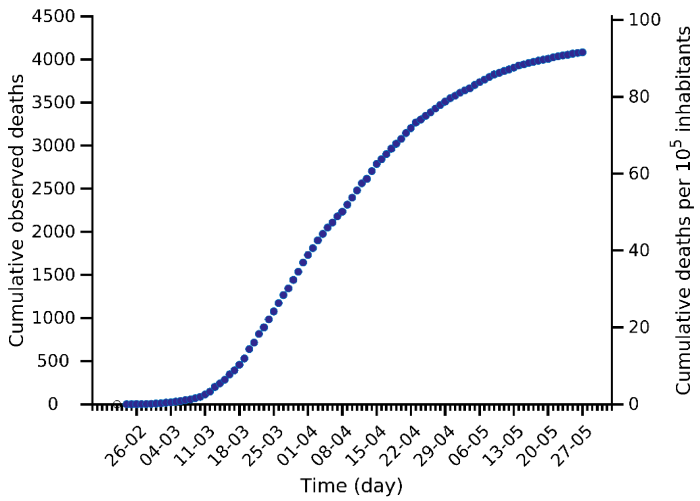



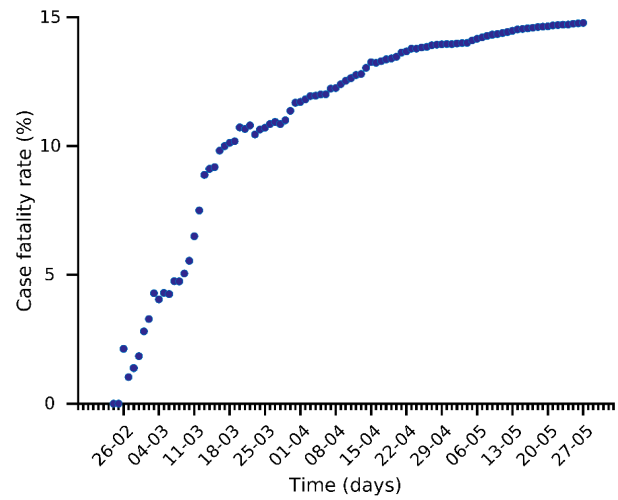



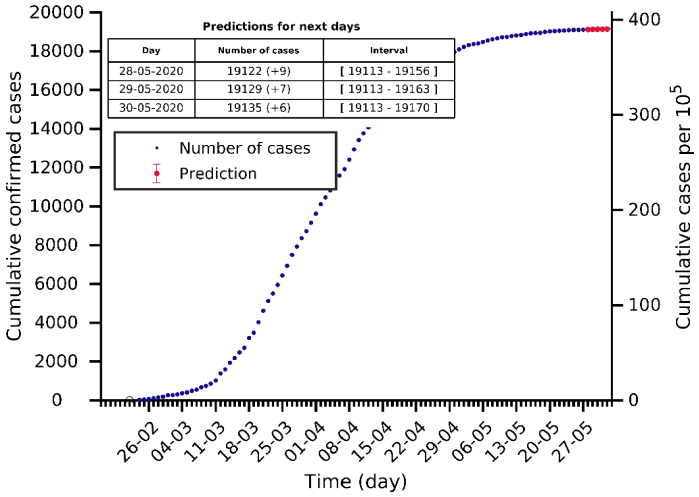



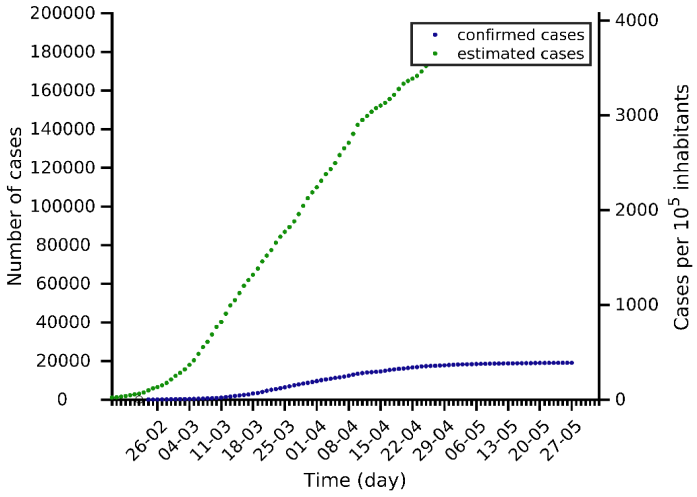



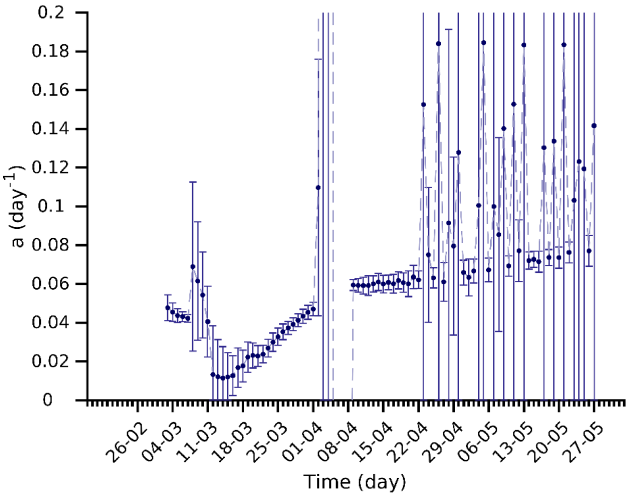



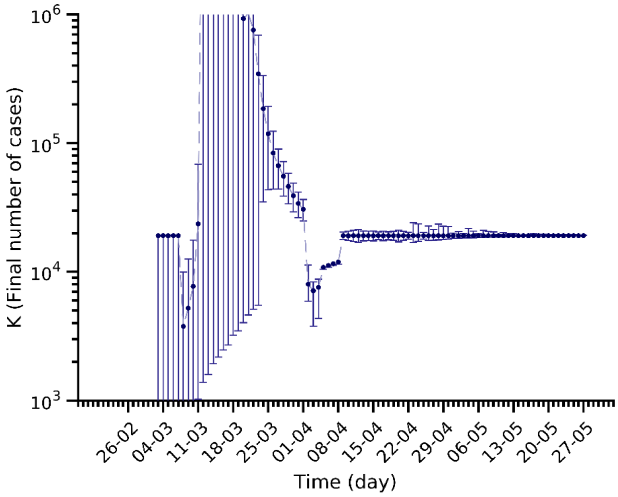



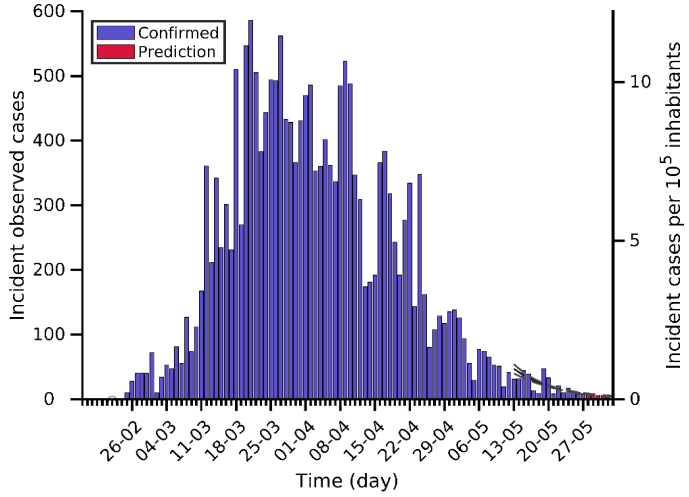
# Veneto 27-05-2020. Population: 4.9M. Current cumulated incidence: 390/10⁵

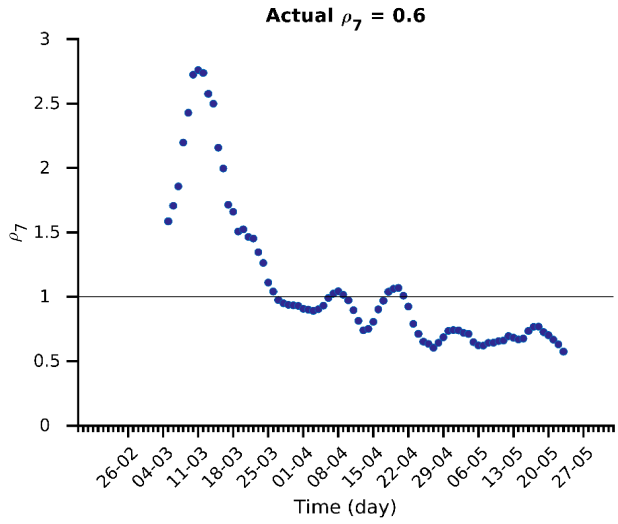


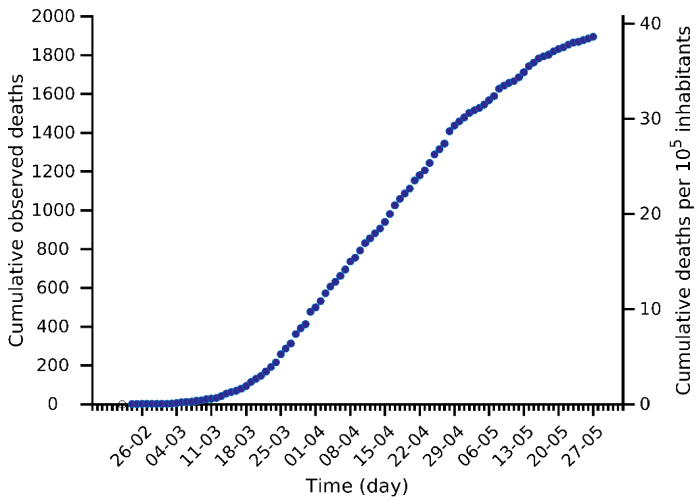



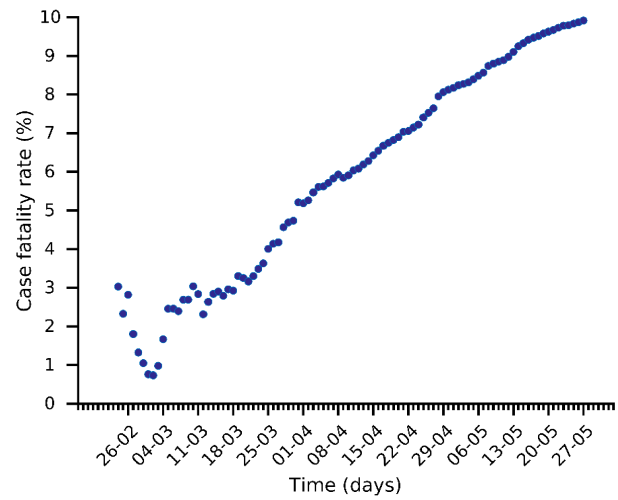



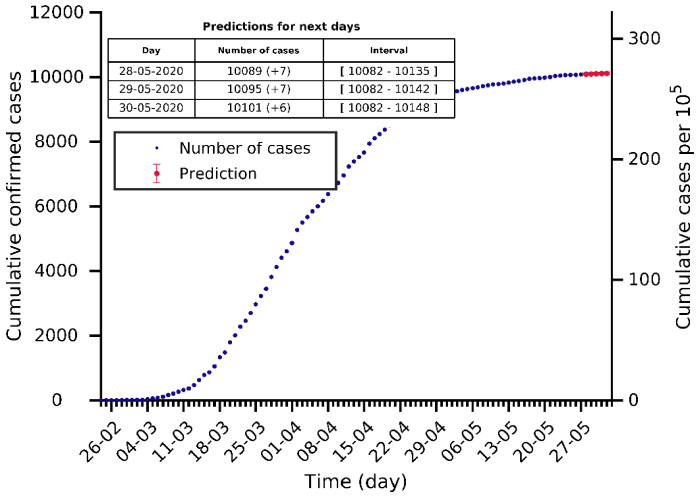



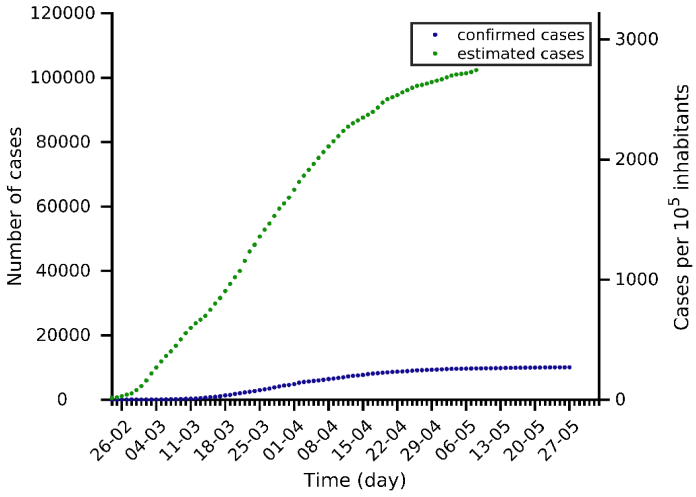



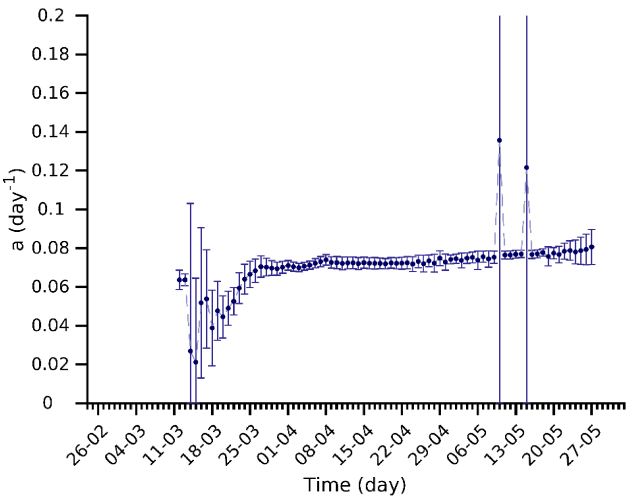



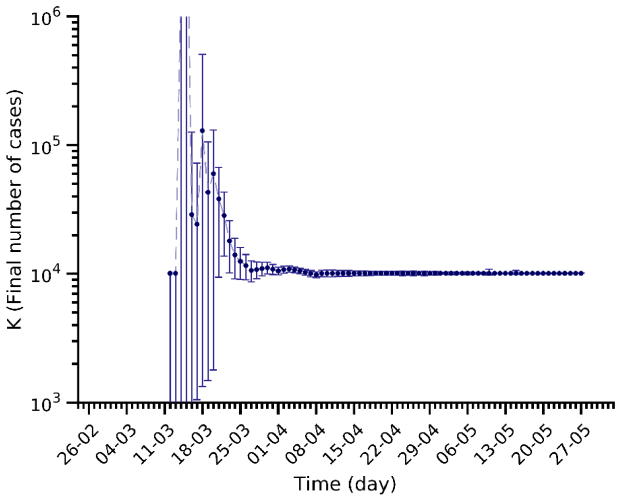



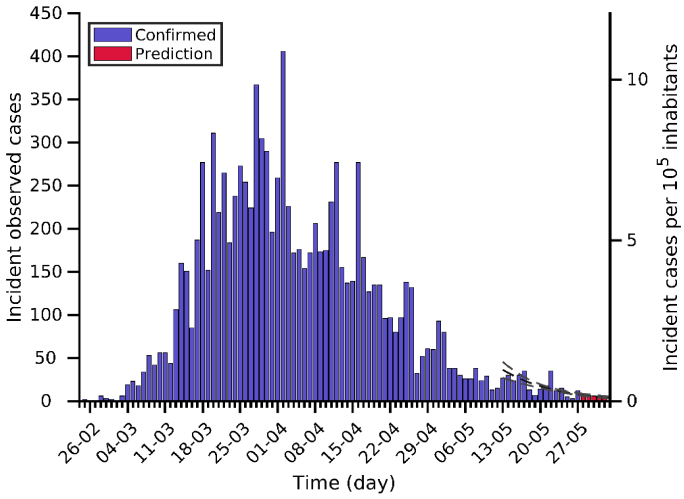
# Toscana 27-05-2020. Population: 3.7M. Current cumulated incidence: 270/10⁵

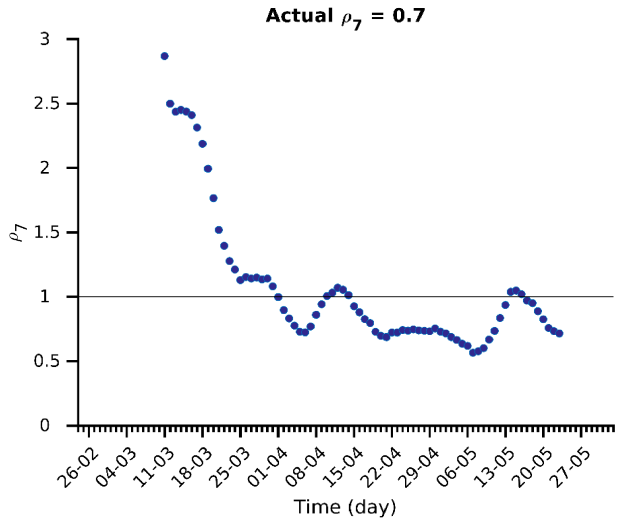


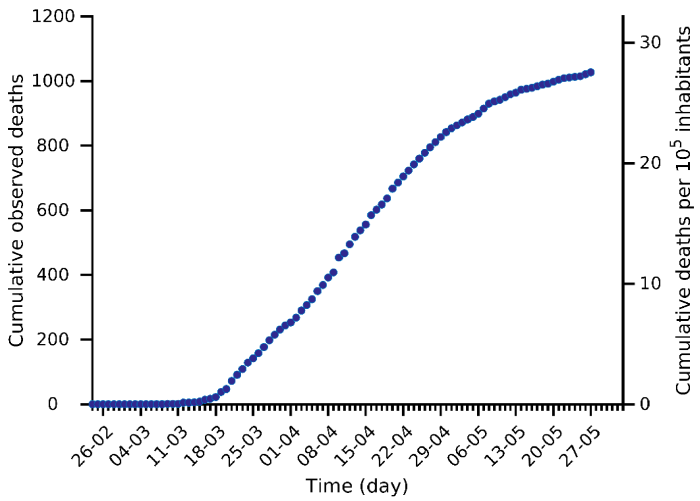



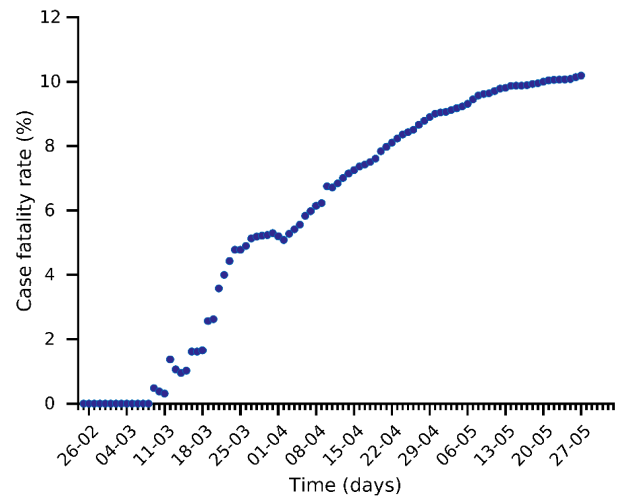



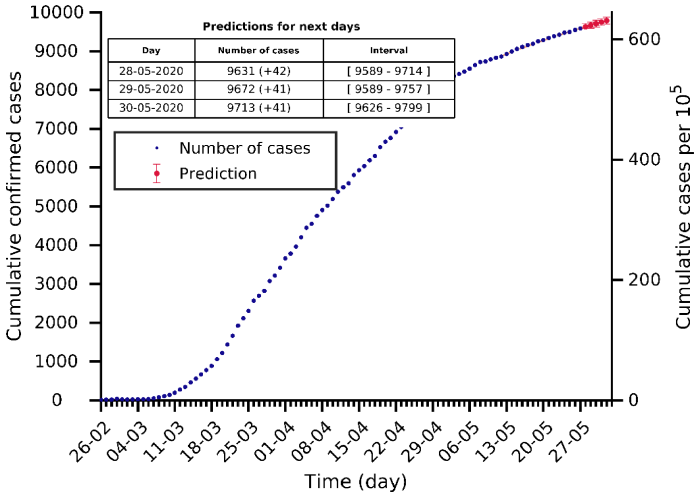



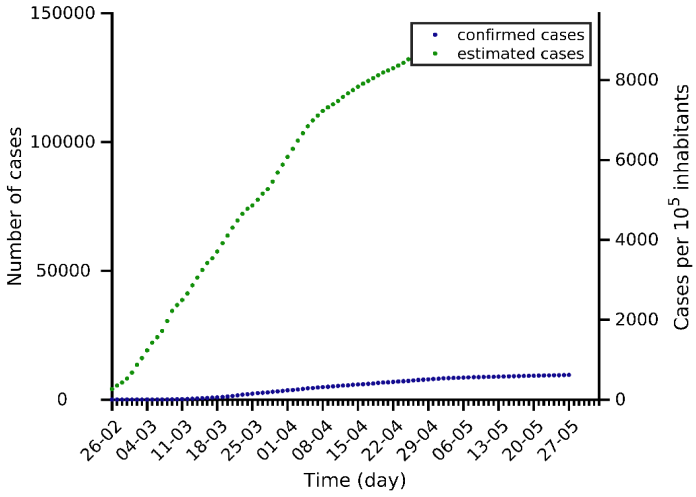



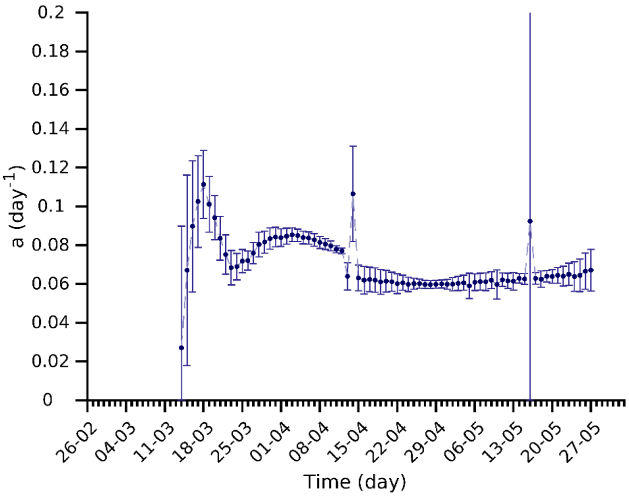



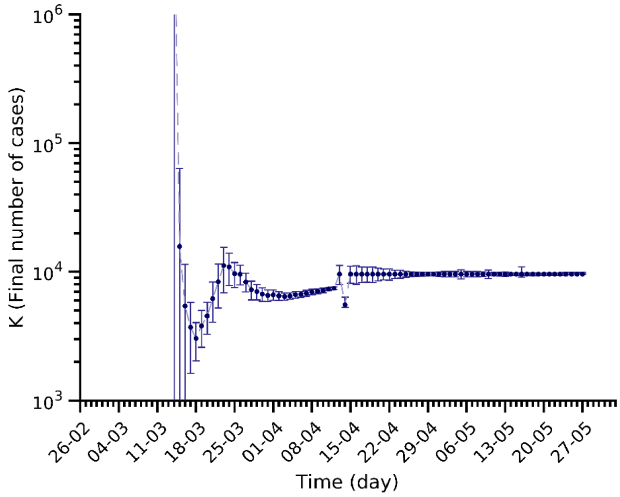



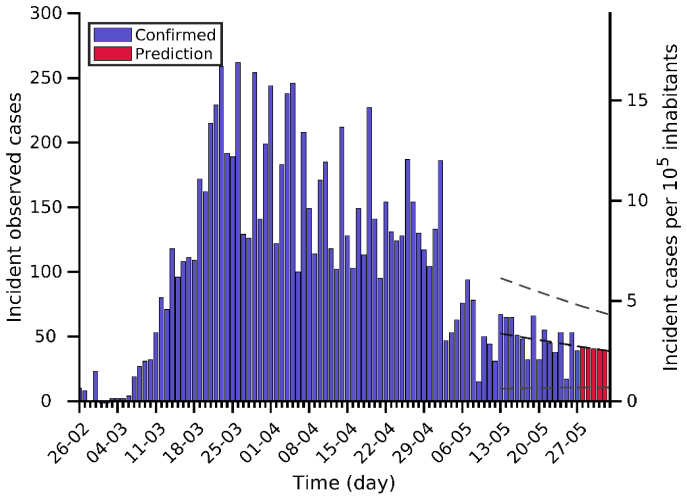
# Liguria 27-05-2020. Population: 1.6M. Current cumulated incidence: 618/10⁵

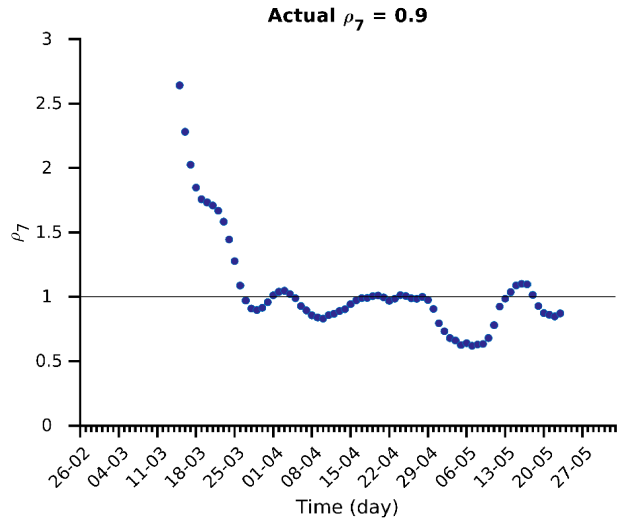


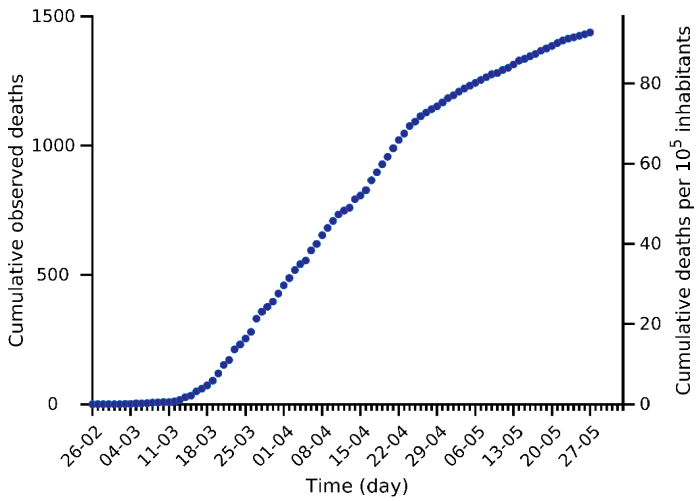



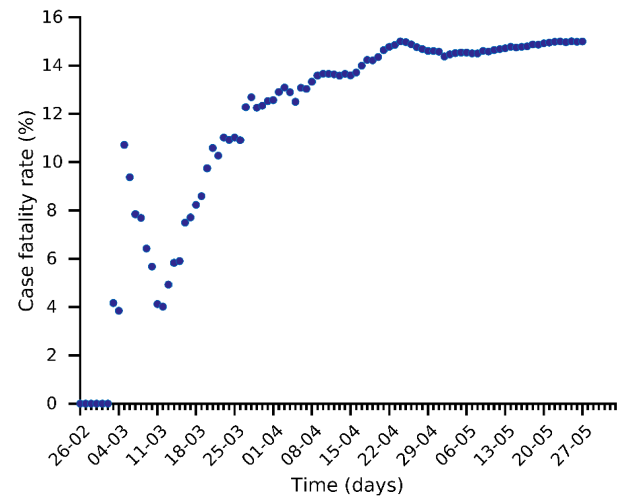



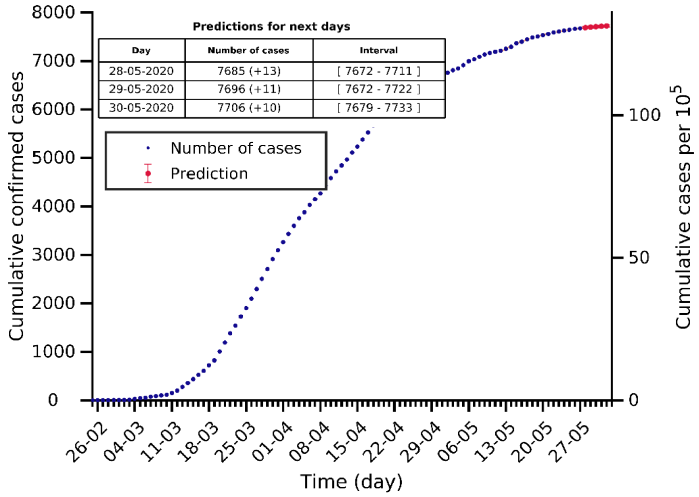



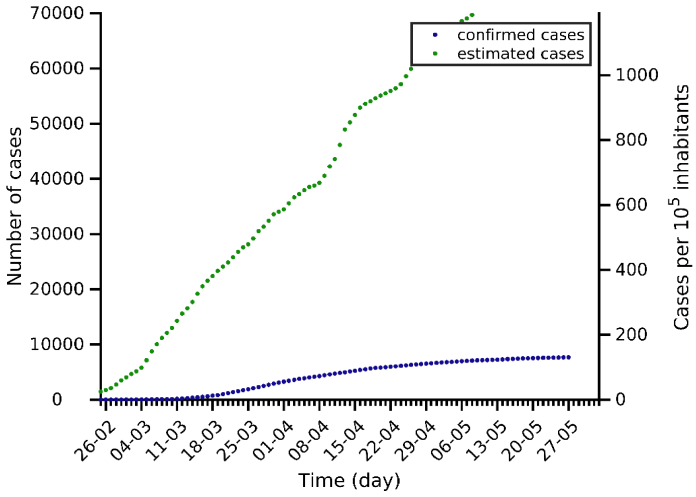



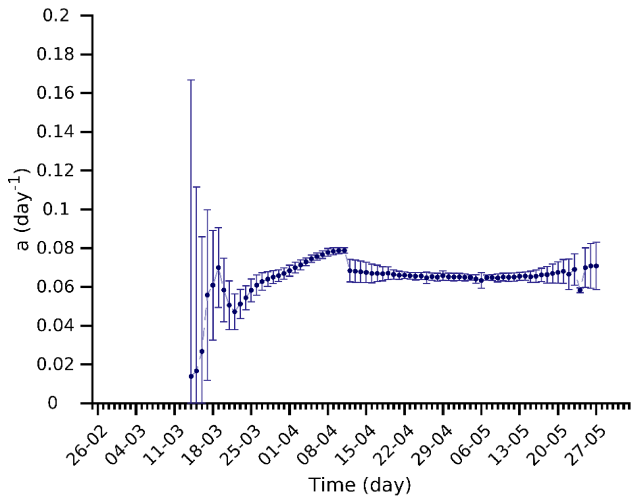



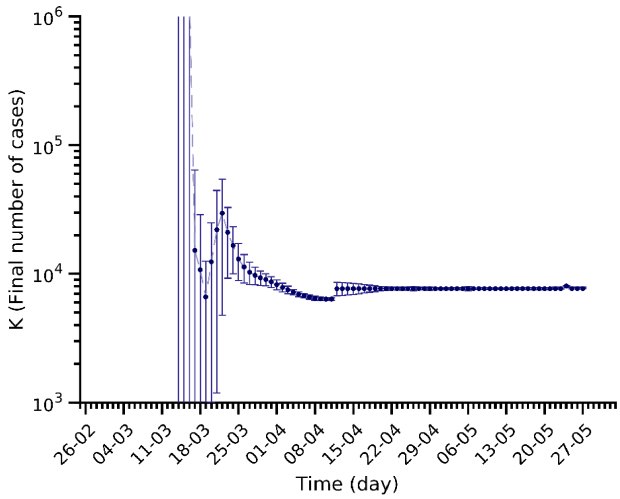



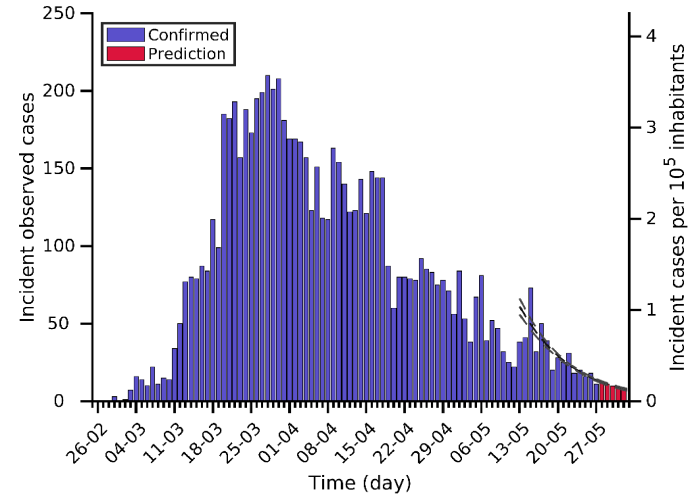
# Lazio 27-05-2020. Population: 5.9M. Current cumulated incidence: 130/10⁵

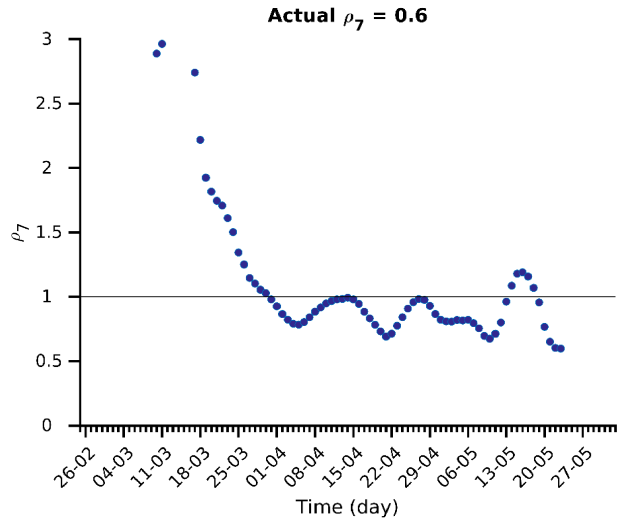


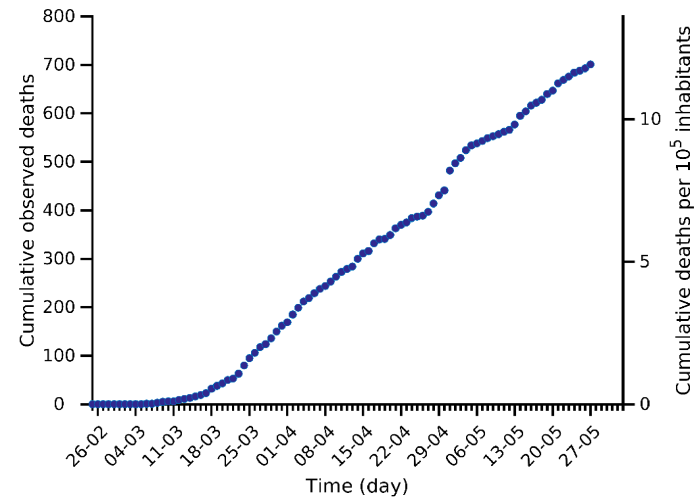



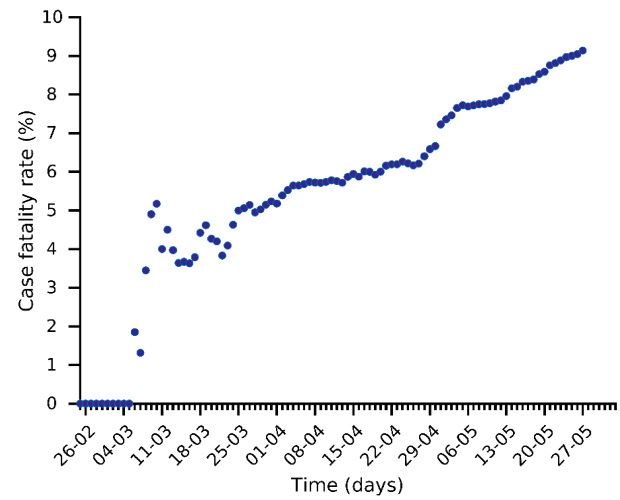



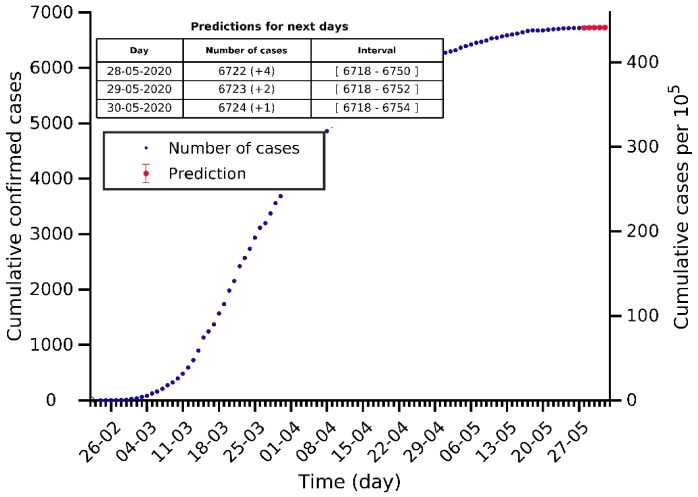



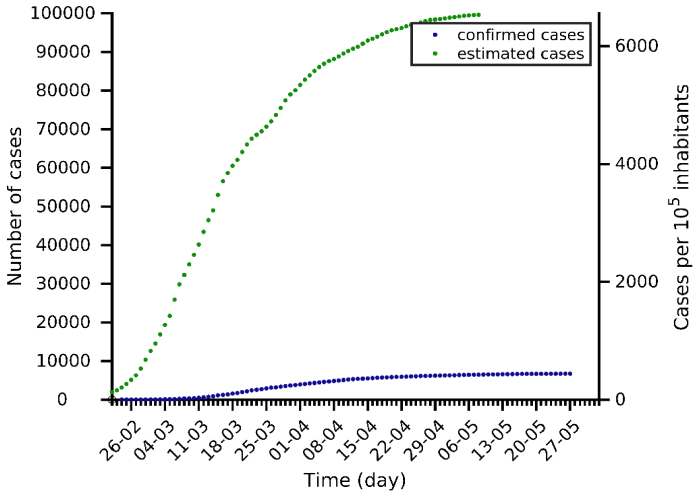



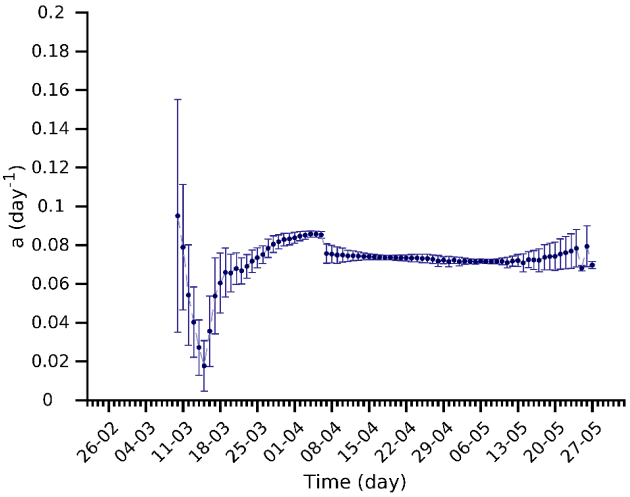



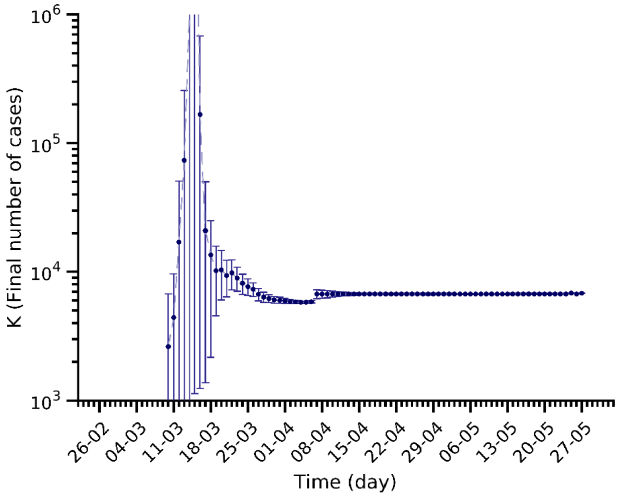



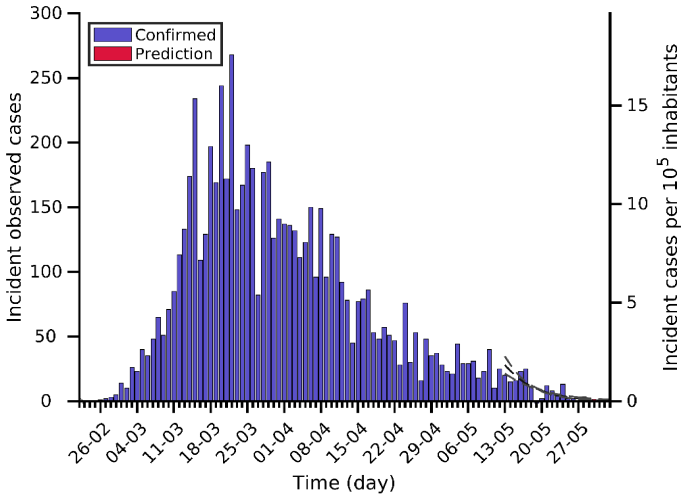
# Marche 27-05-2020. Population: 1.5M. Current cumulated incidence: 441/10⁵

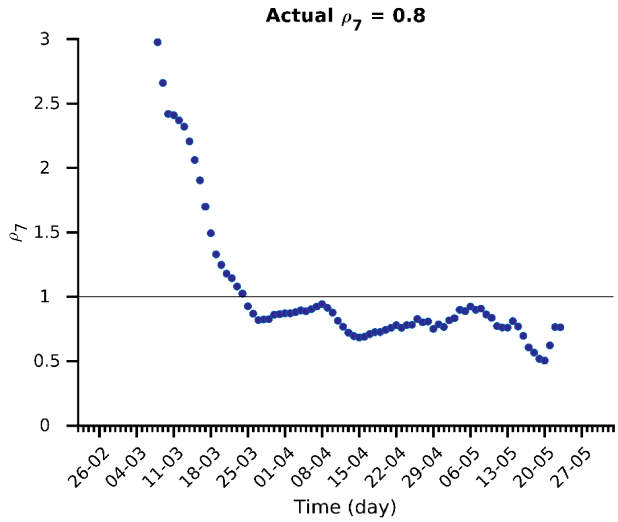


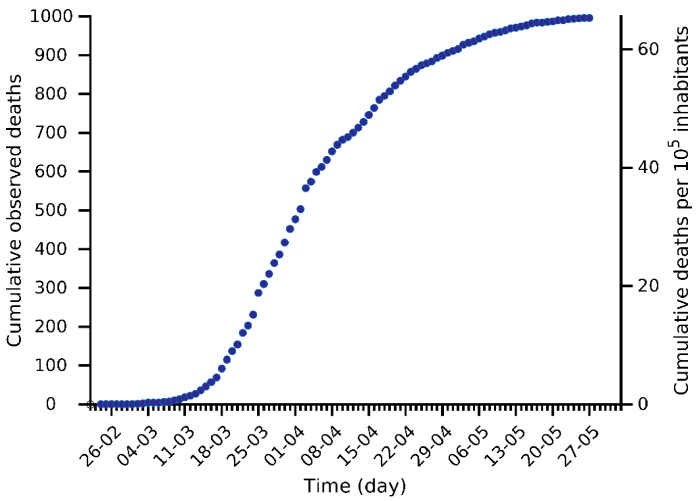



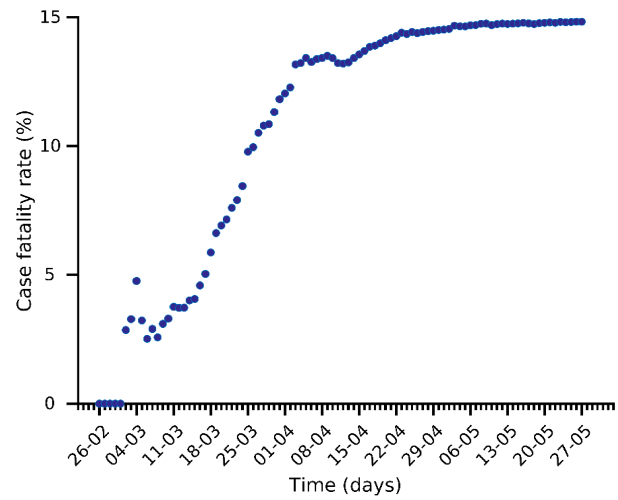



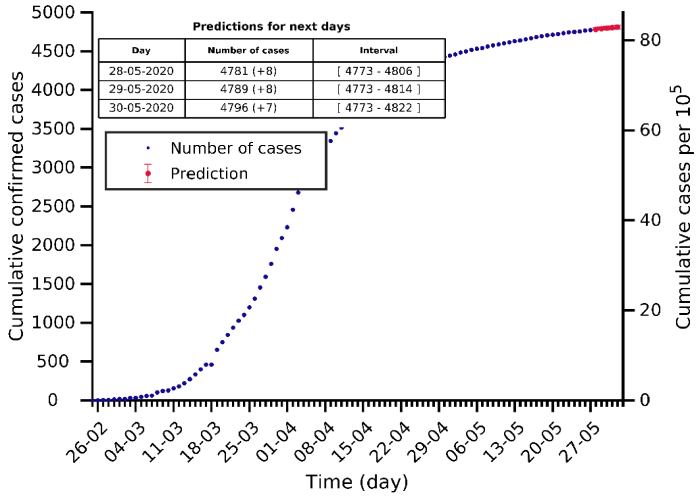



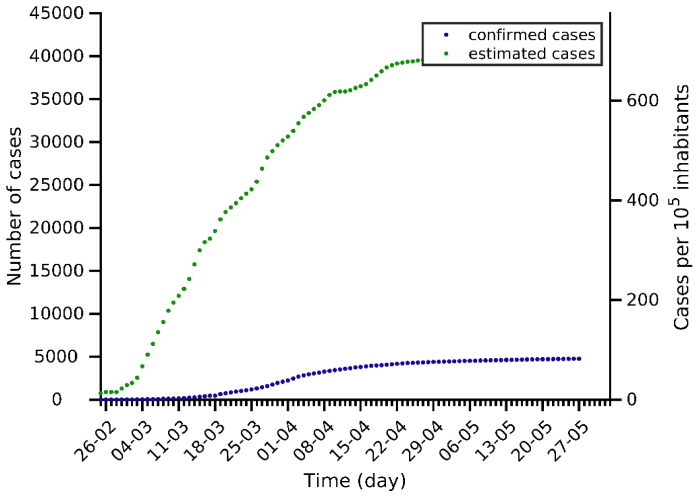



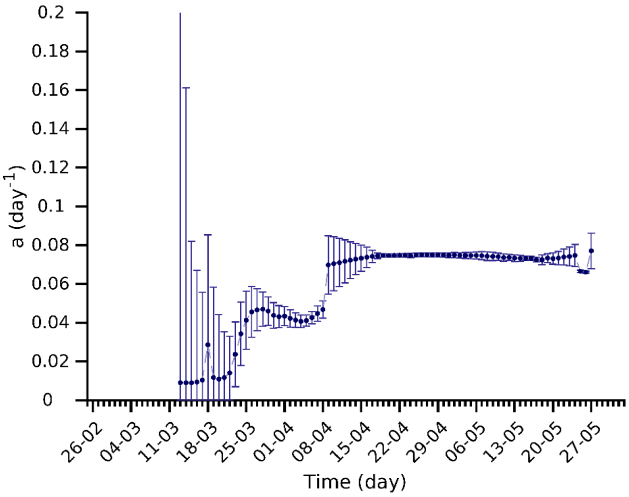



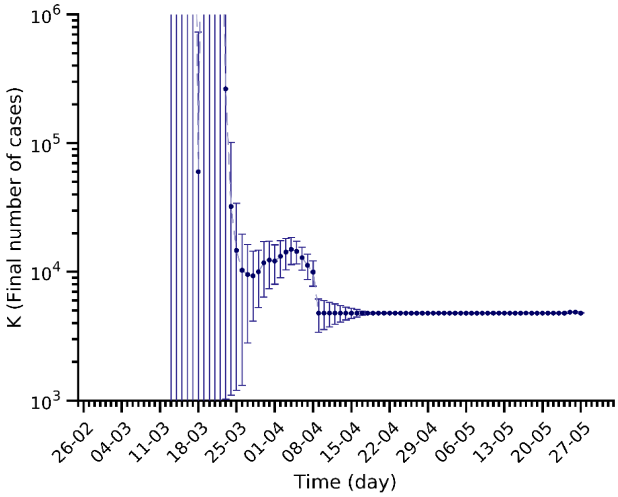



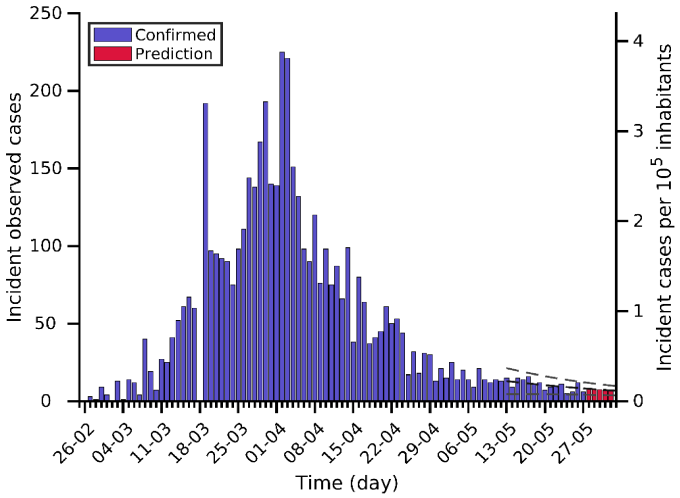
# Campania 27-05-2020. Population: 5.8M. Current cumulated incidence: 82/$10^5$

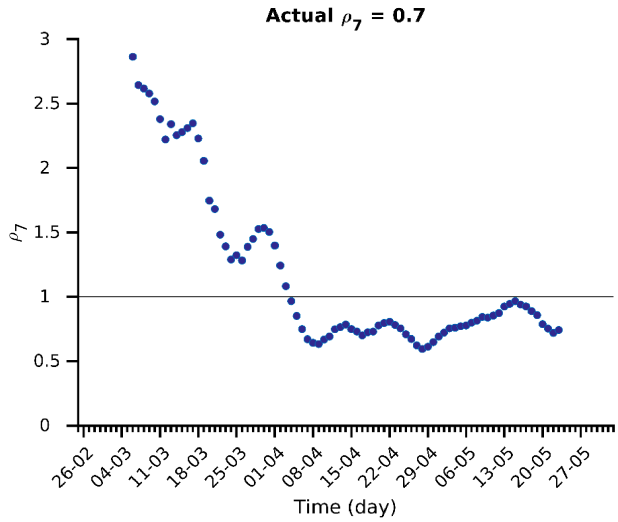


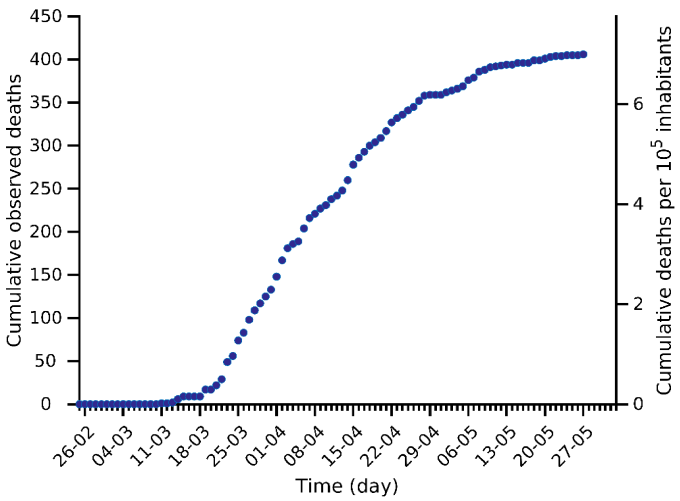



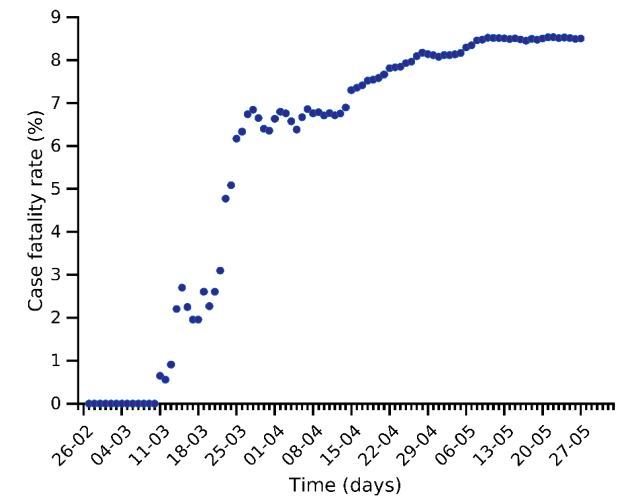



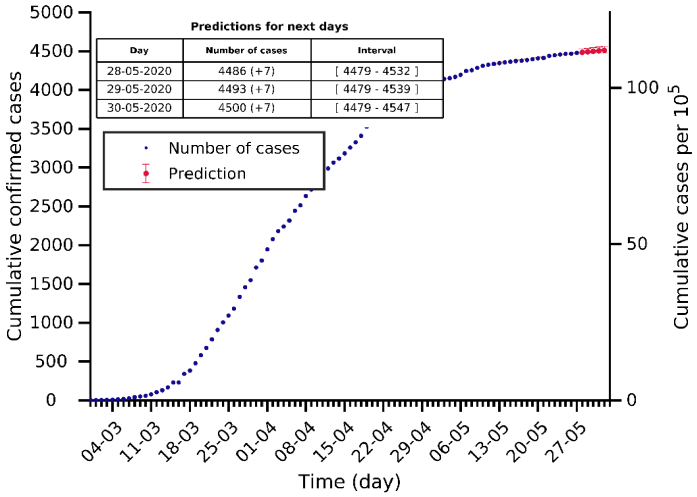



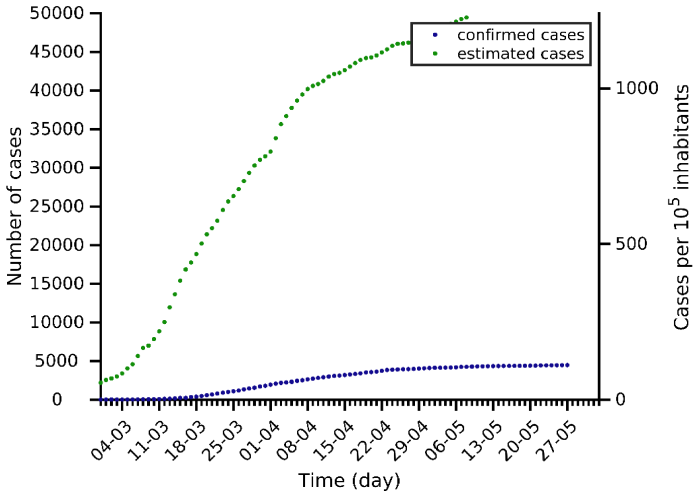



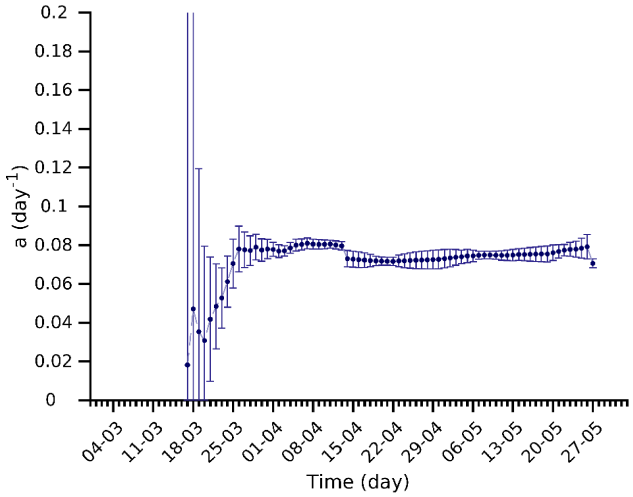



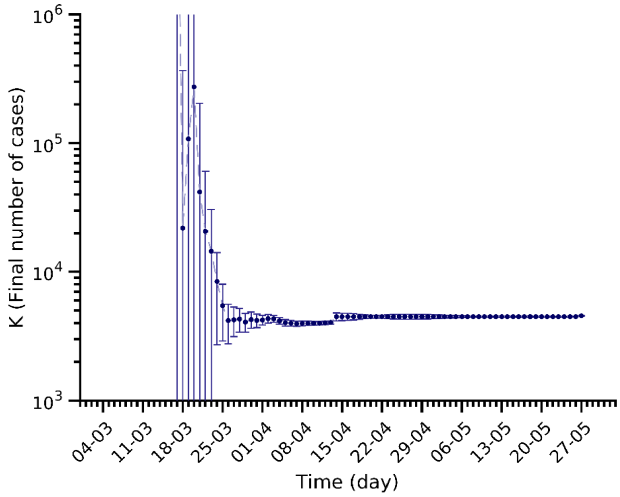



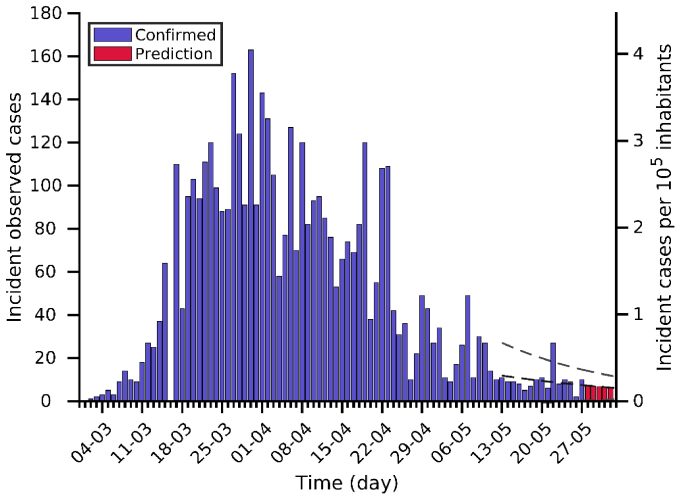
# Puglia 27-05-2020. Population: 4.0M. Current cumulated incidence: 111/10$^5$

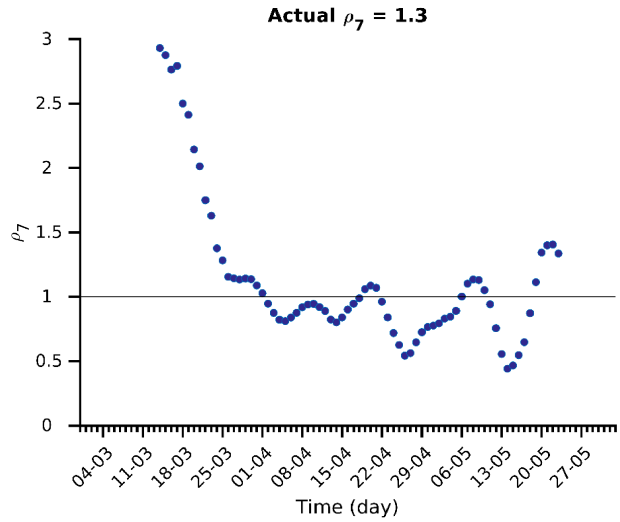


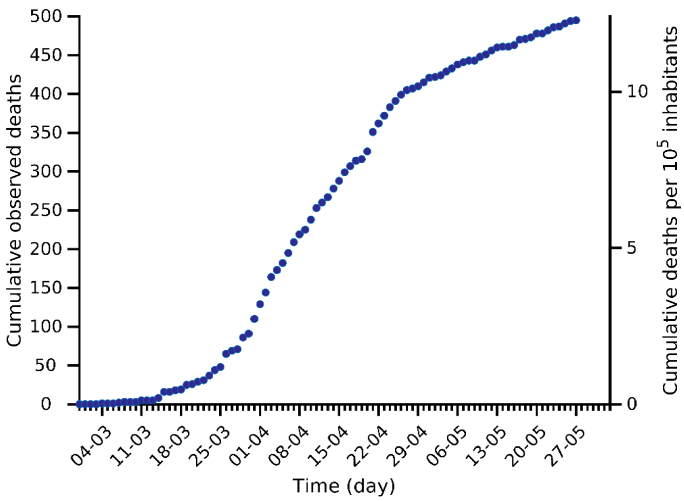



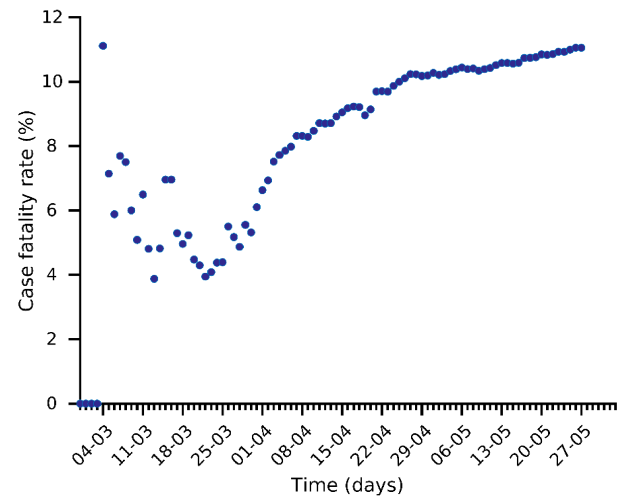



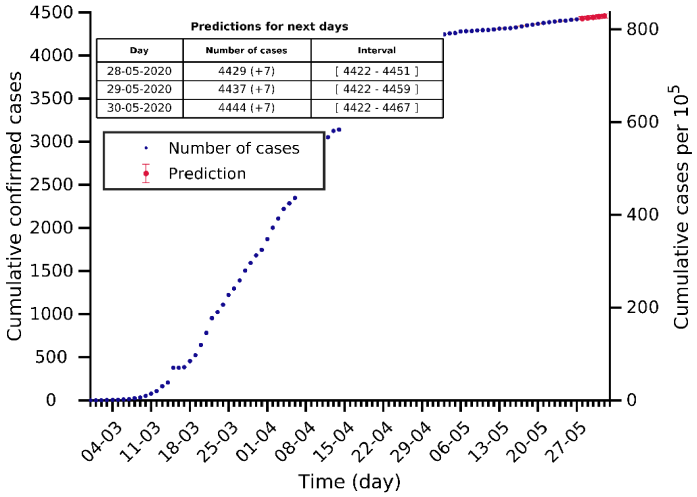



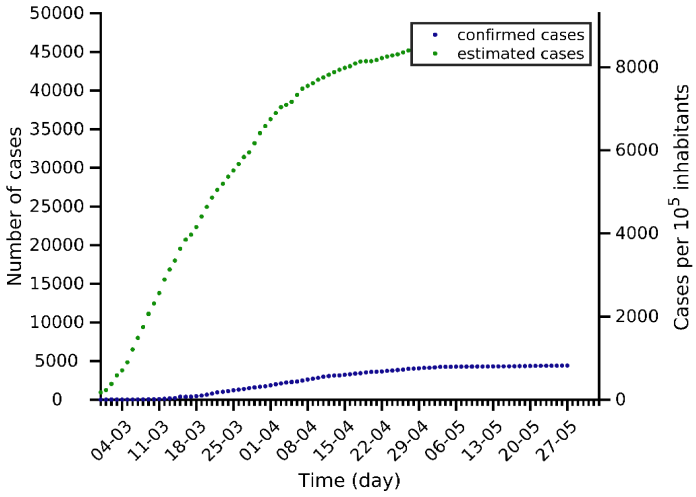



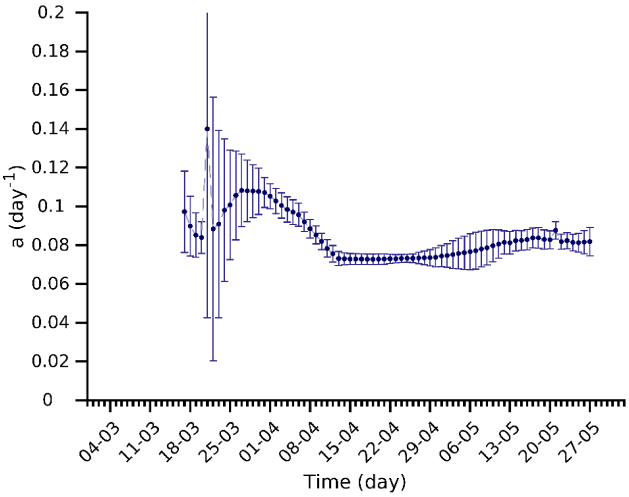



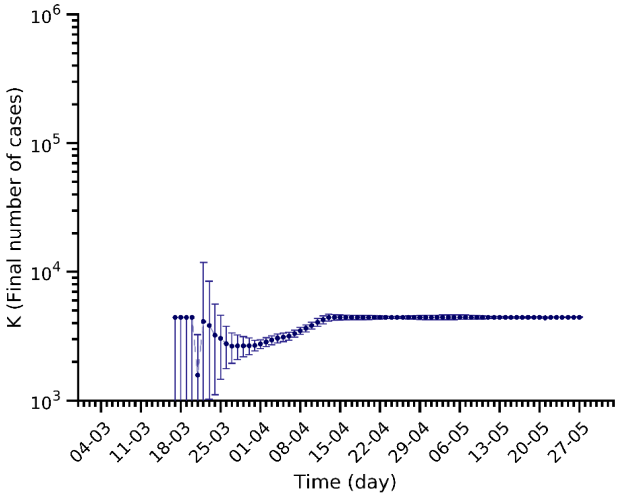



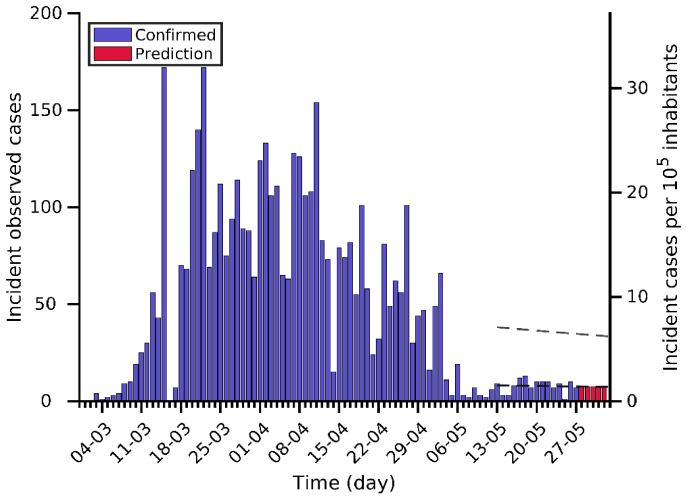
# Trento 27-05-2020. Population: 0.5M. Current cumulated incidence: 822/$10^5$

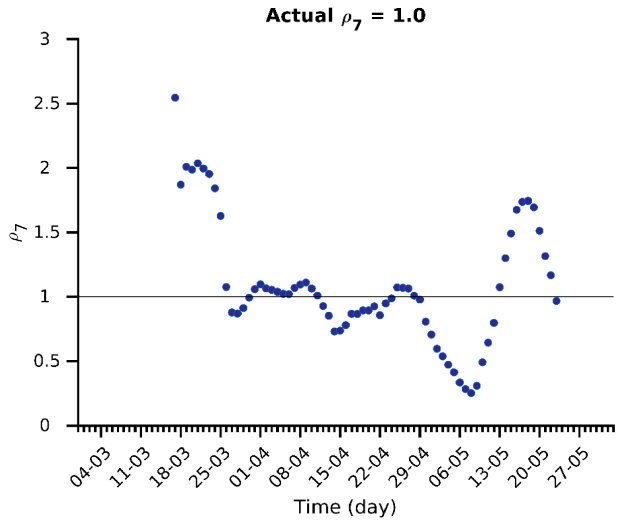


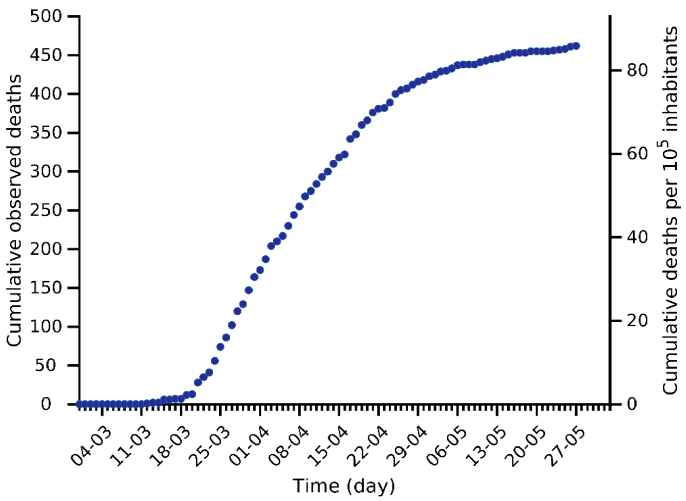



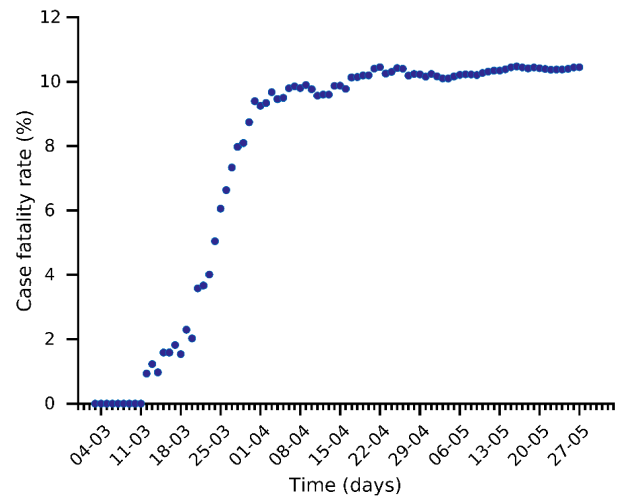



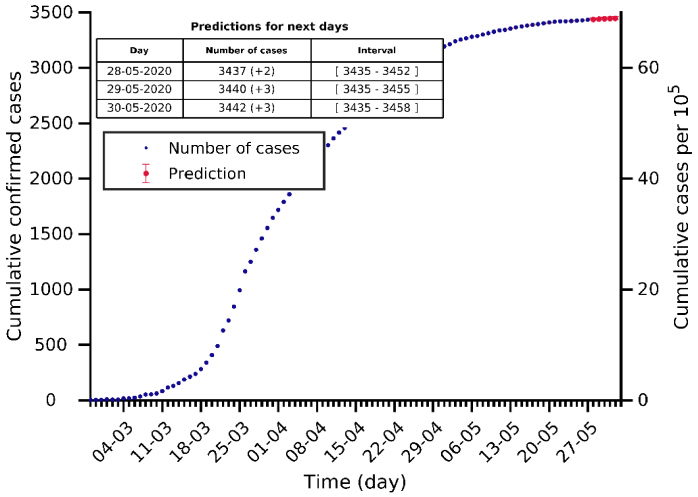



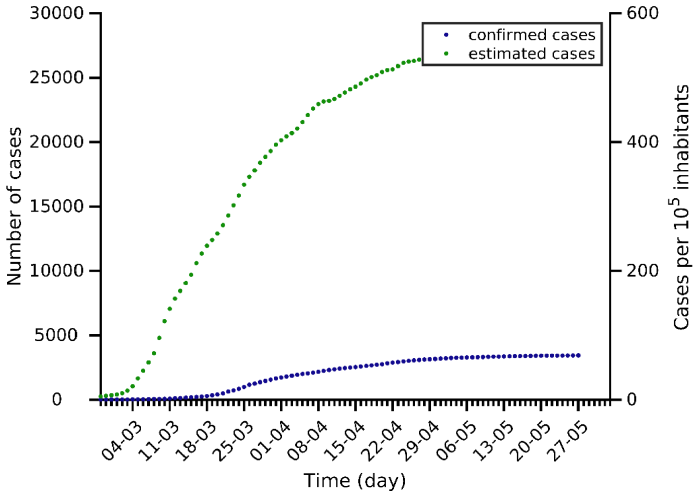



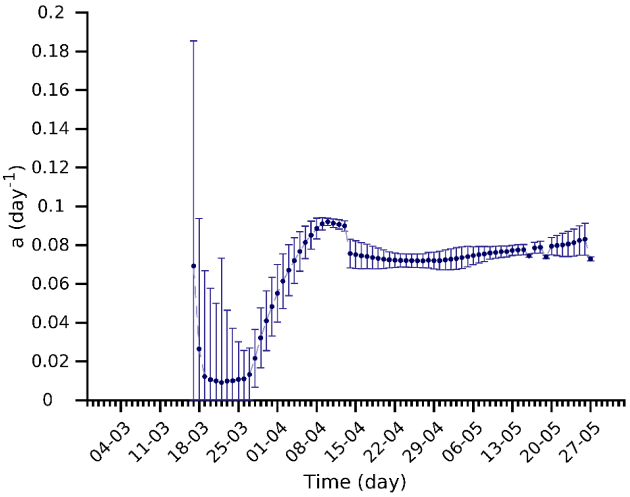



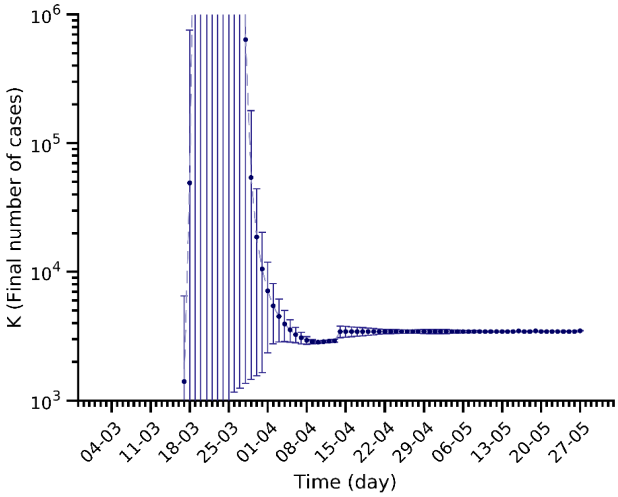



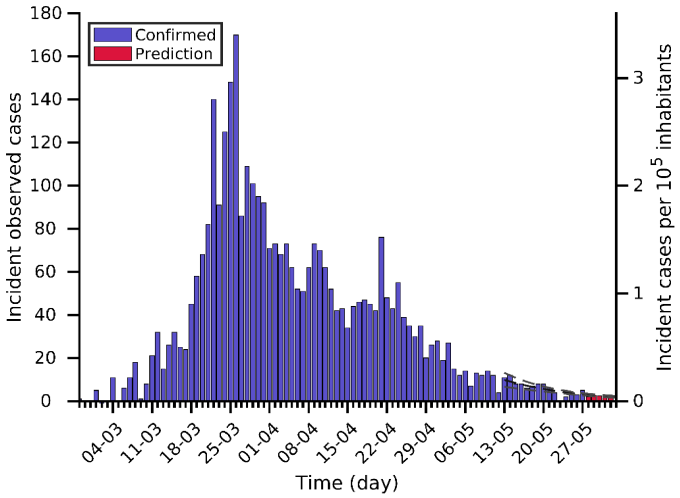
# Sicilia 27-05-2020. Population: 5.0M. Current cumulated incidence: 69/$10^5$

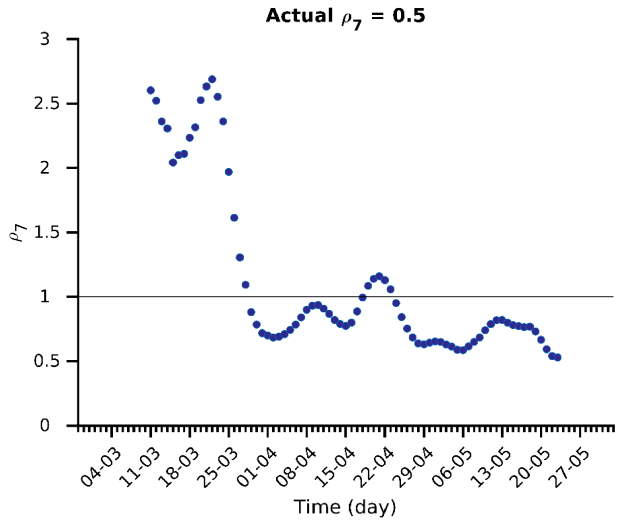


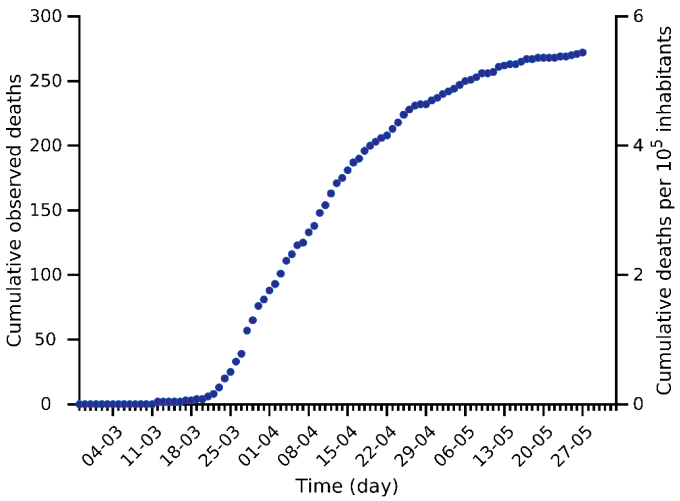



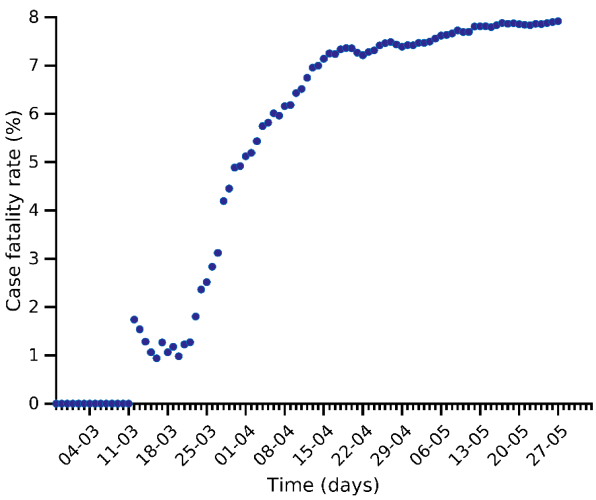



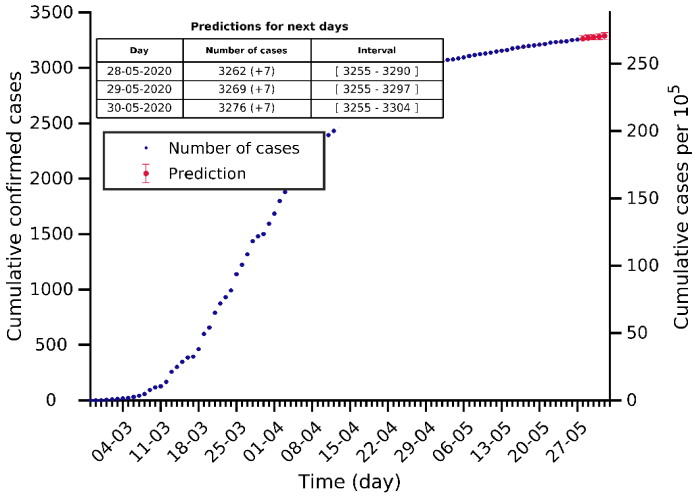



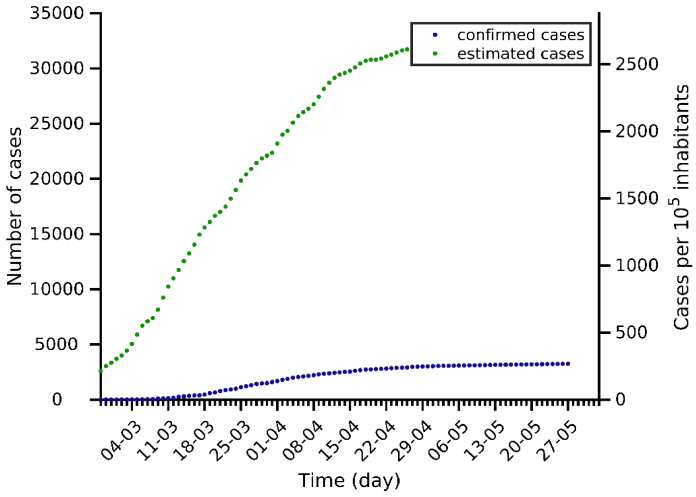



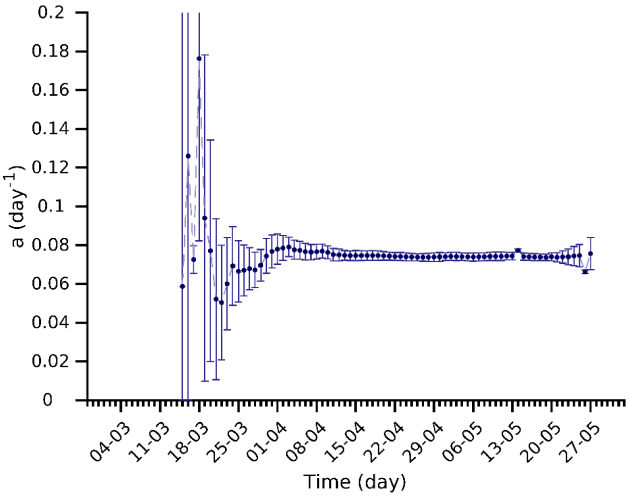



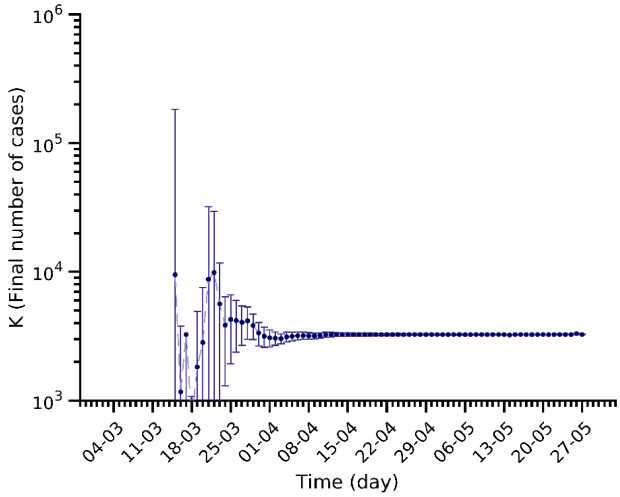



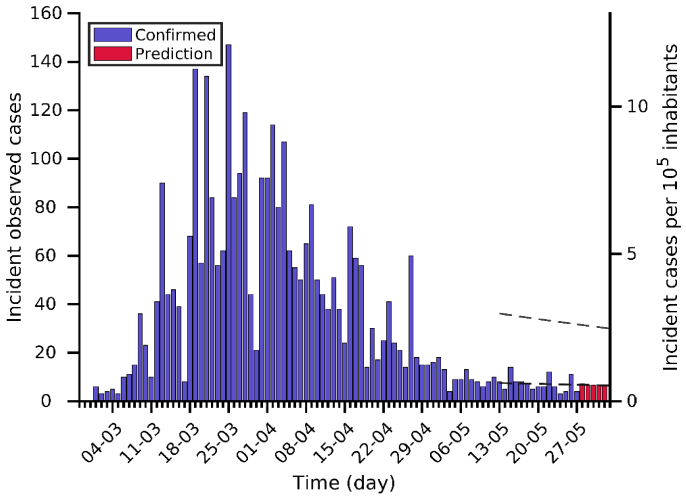
# Friuli Venezia Giulia 27-05-2020. Population: 1.2M. Current cumulated incidence: 2

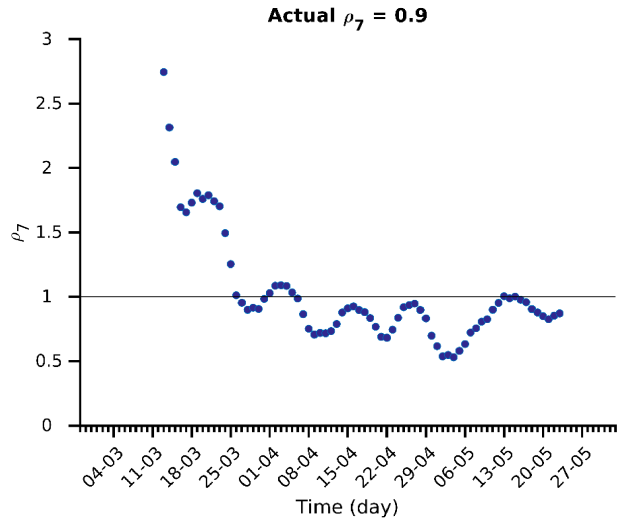


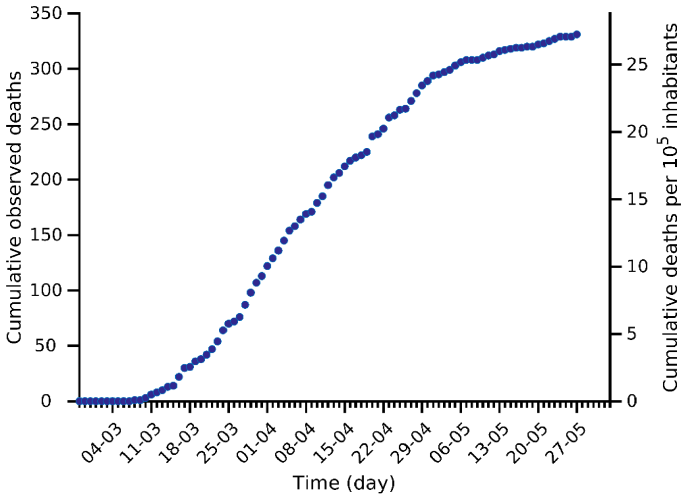



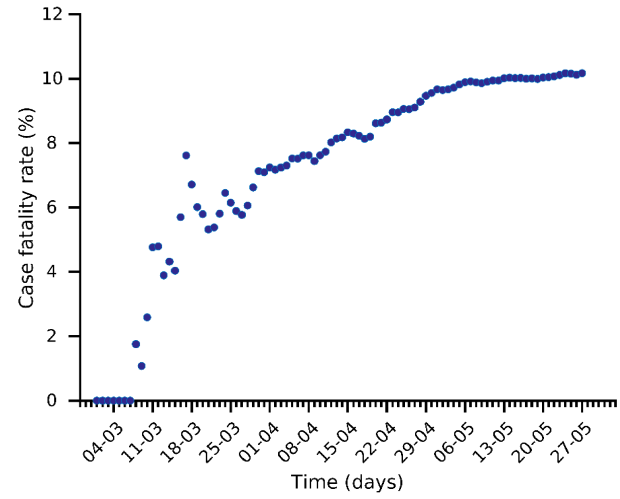



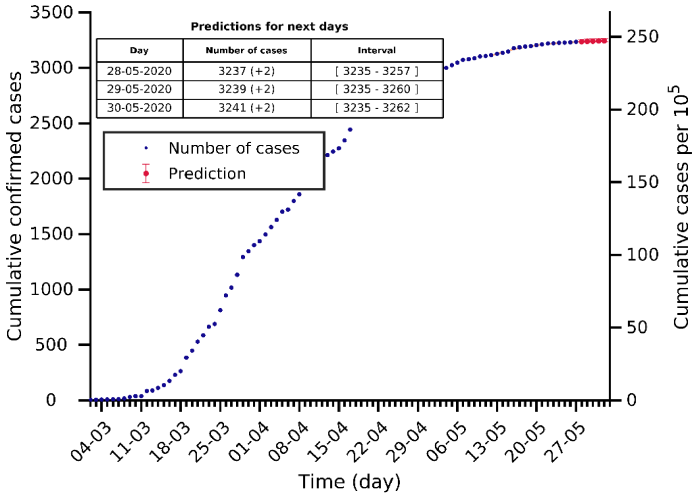



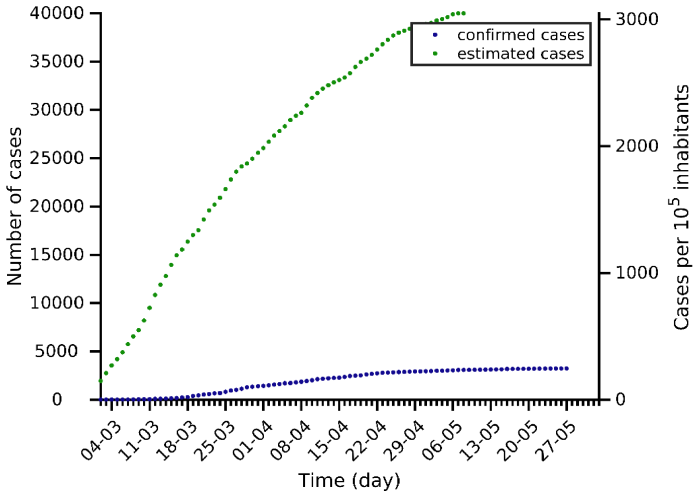



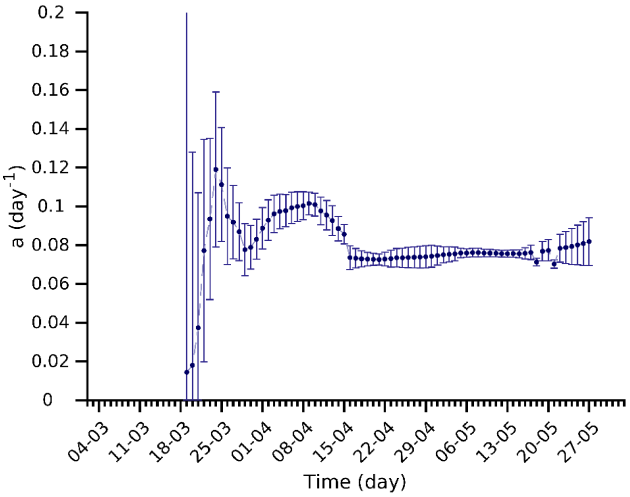



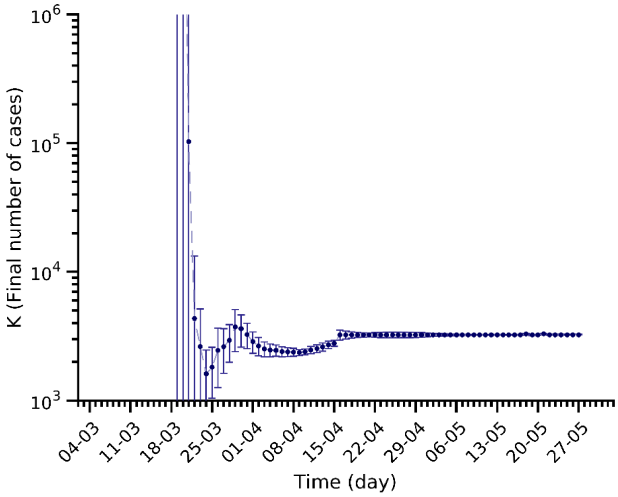



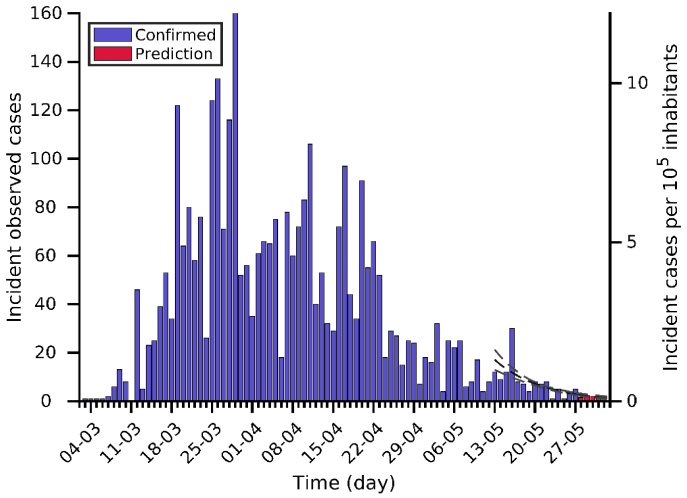
# Abruzzo 27-05-2020. Population: 1.3M. Current cumulated incidence: 247/$10^5$

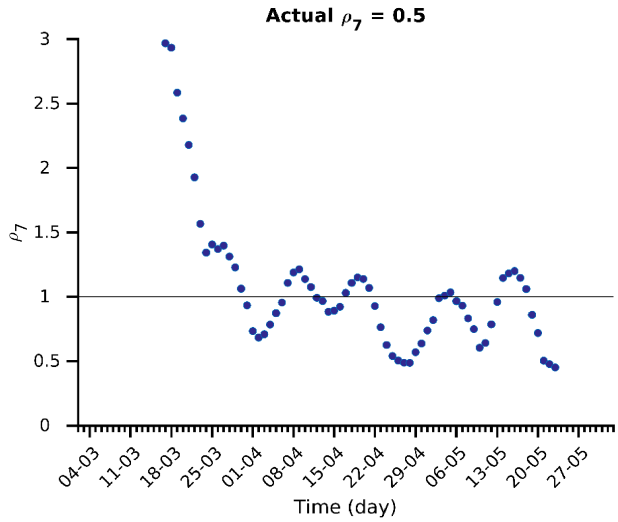


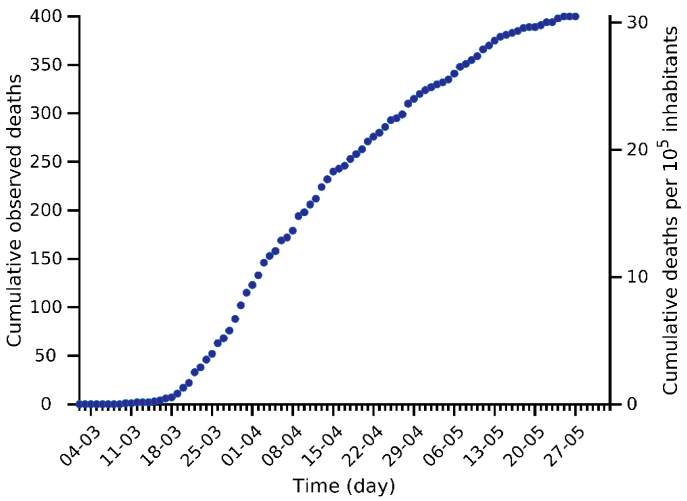



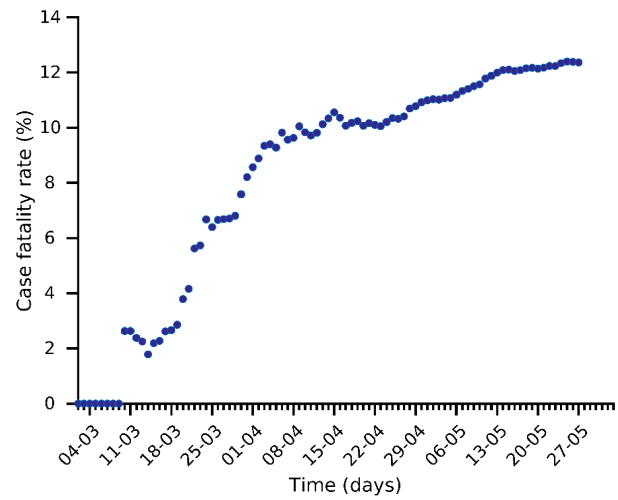



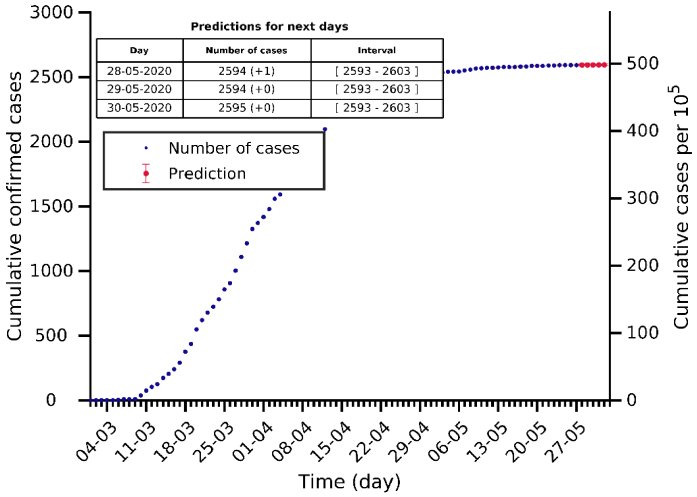



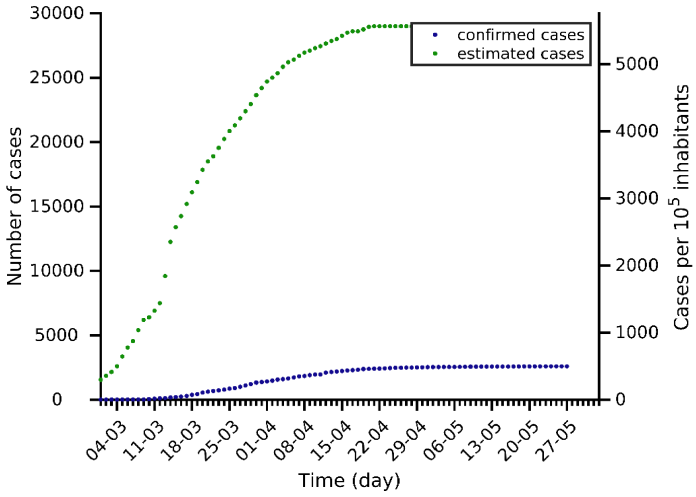



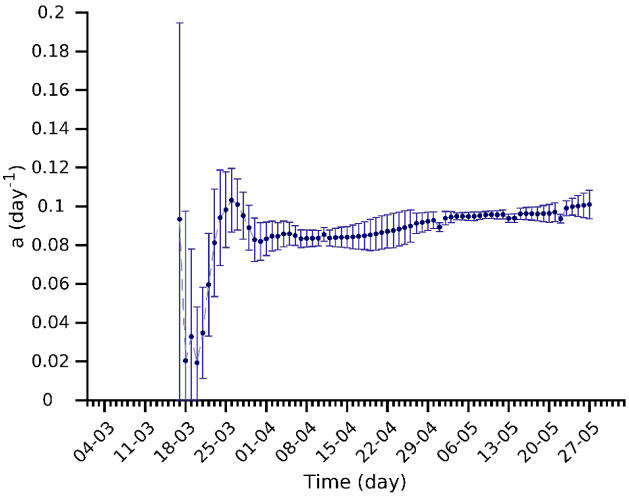



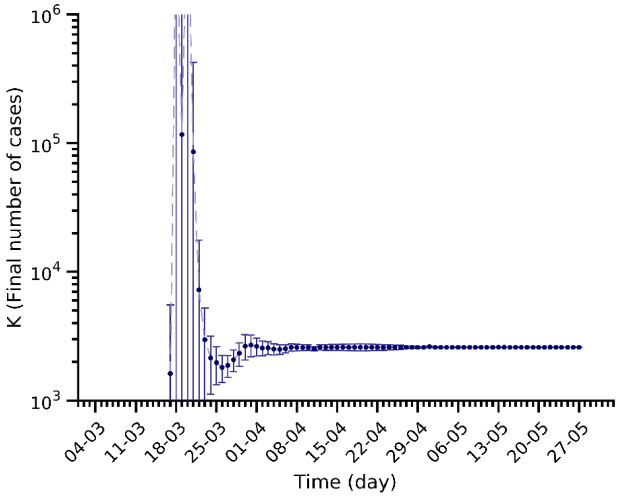



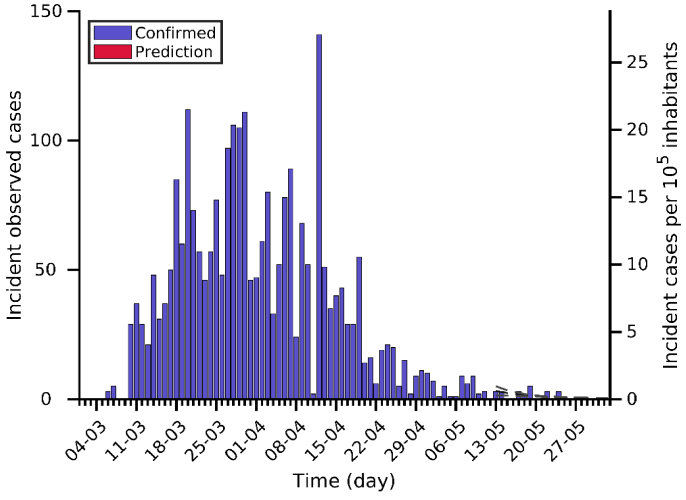
# Bolzano 27-05-2020. Population: 0.5M. Current cumulated incidence: 498/$10^5$

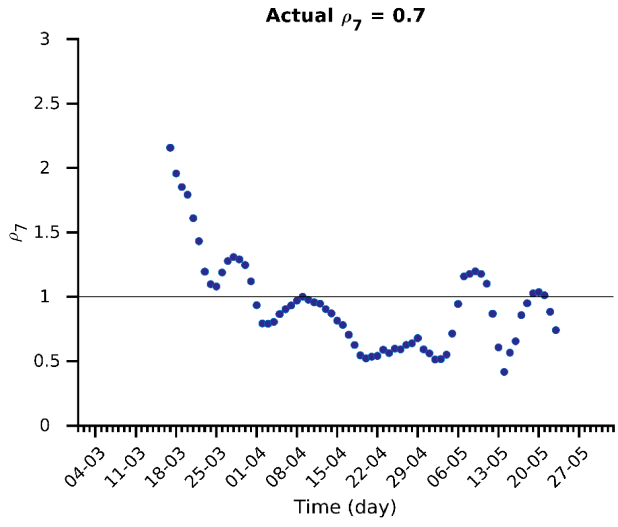


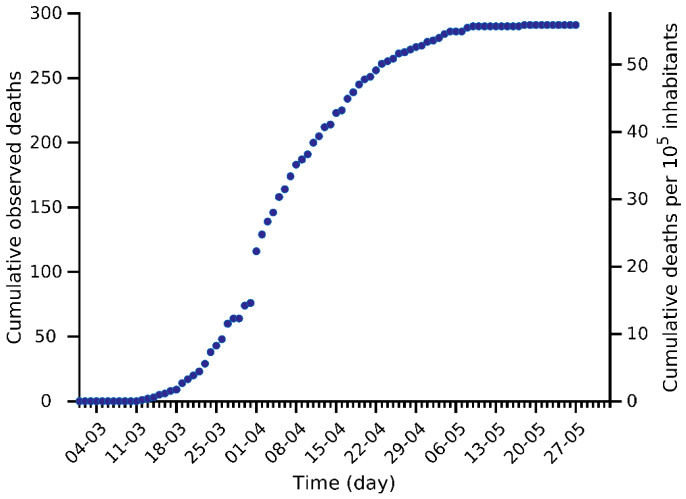



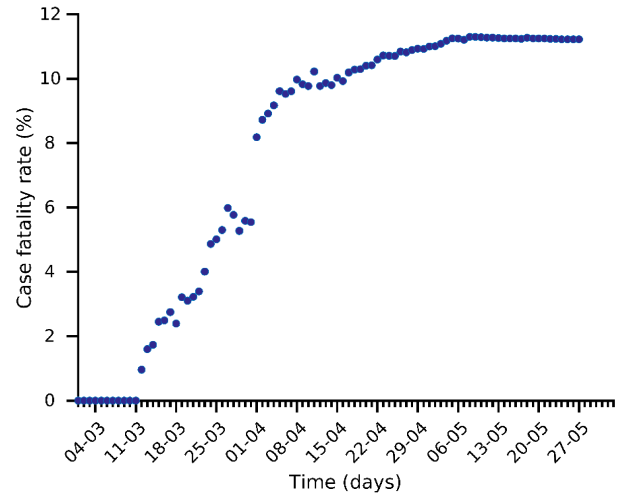



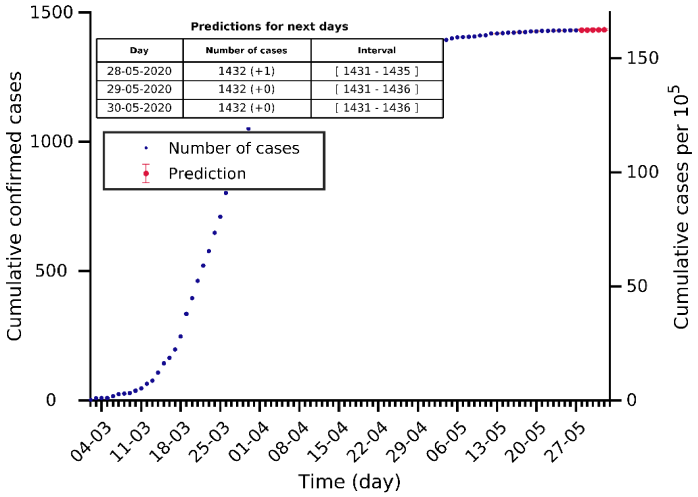



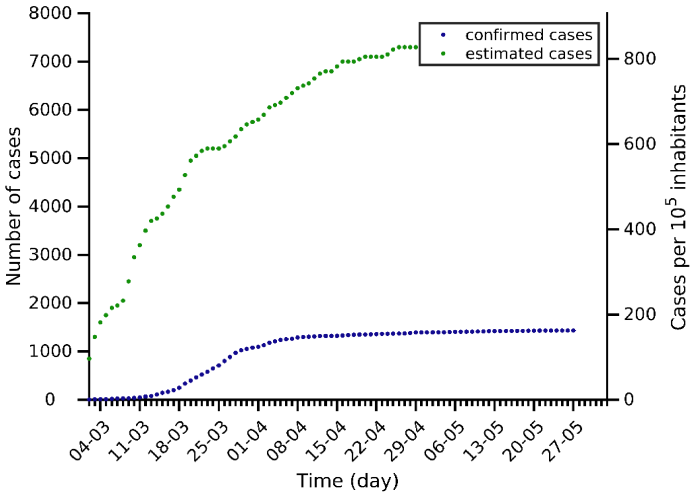



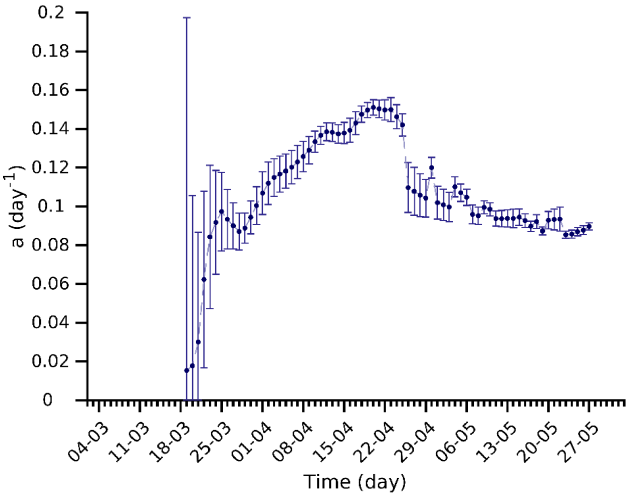



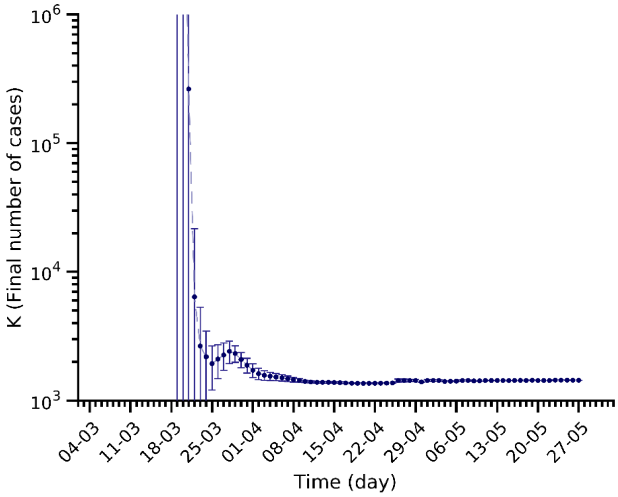



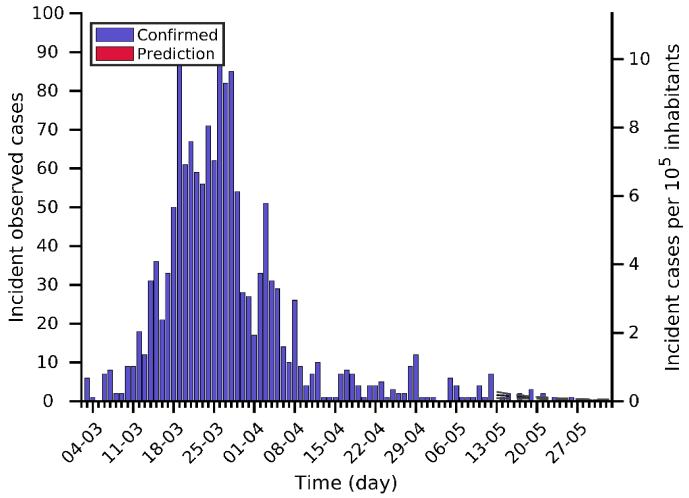
# Umbria 27-05-2020. Population: 0.9M. Current cumulated incidence: 162/$10^5$

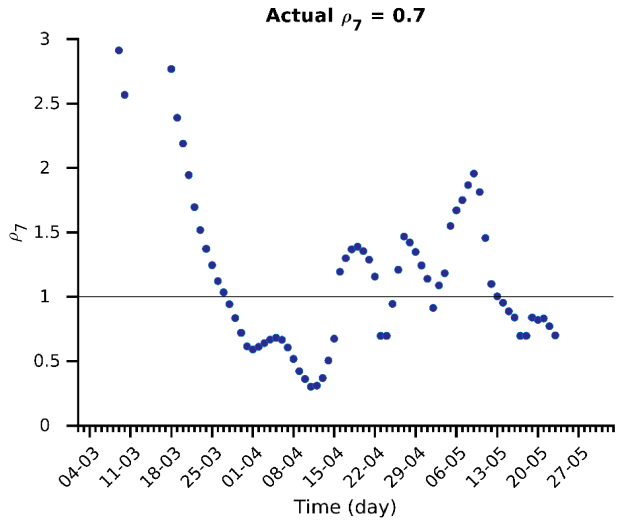


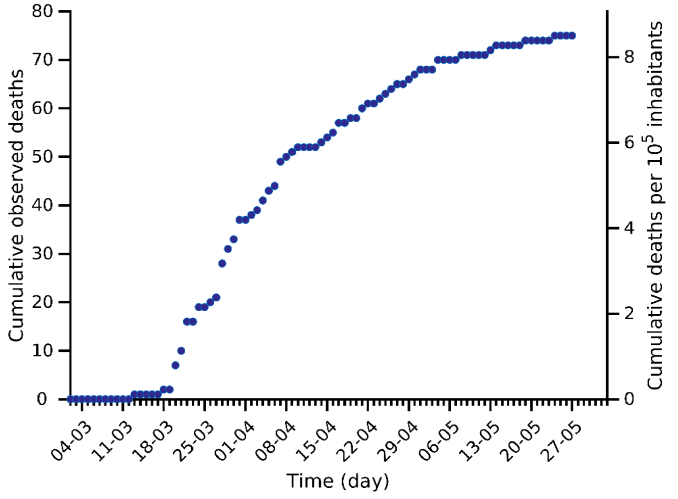



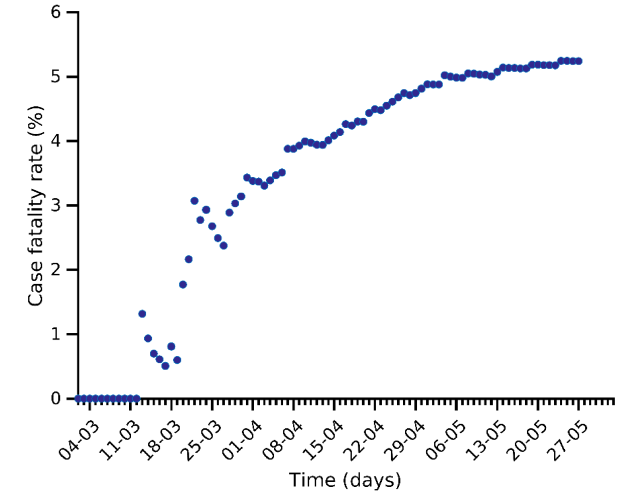



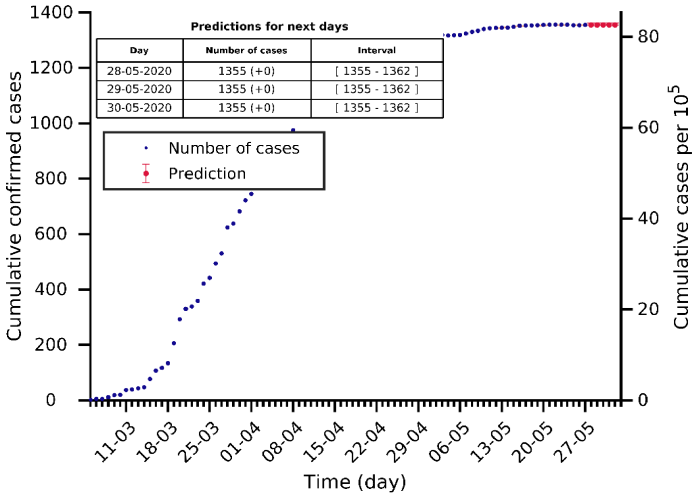



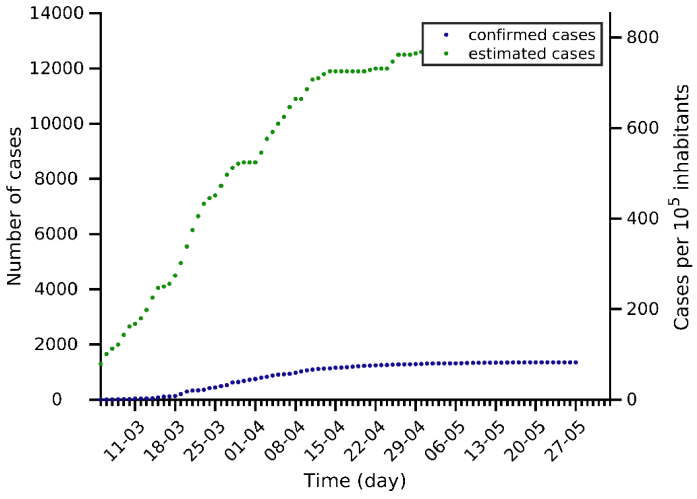



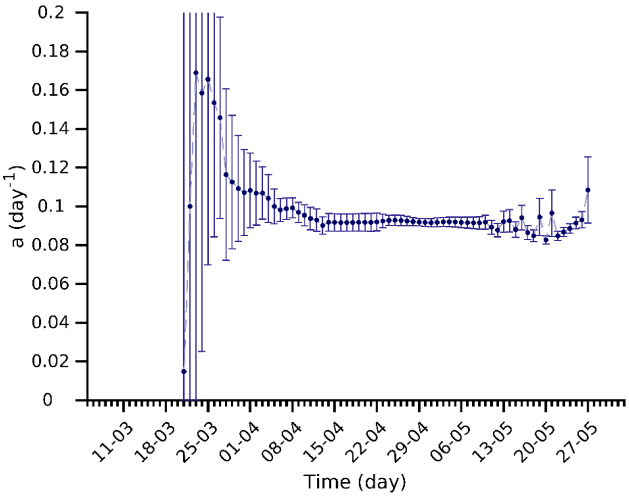
# Sardegna 27-05-2020. Population: 1.6M. Current cumulated incidence: 83/10⁵

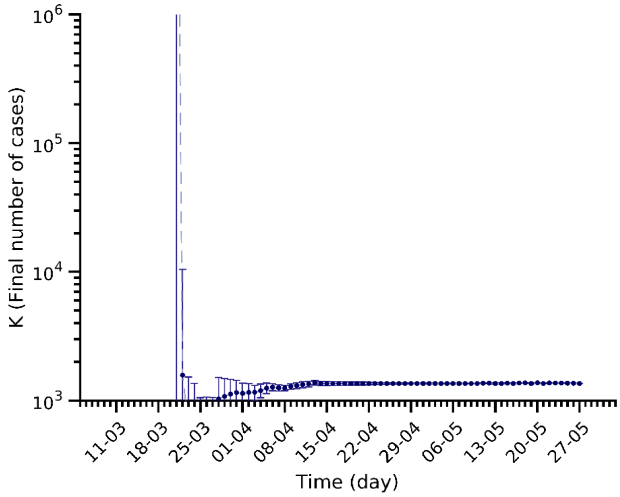
Predictions for next days

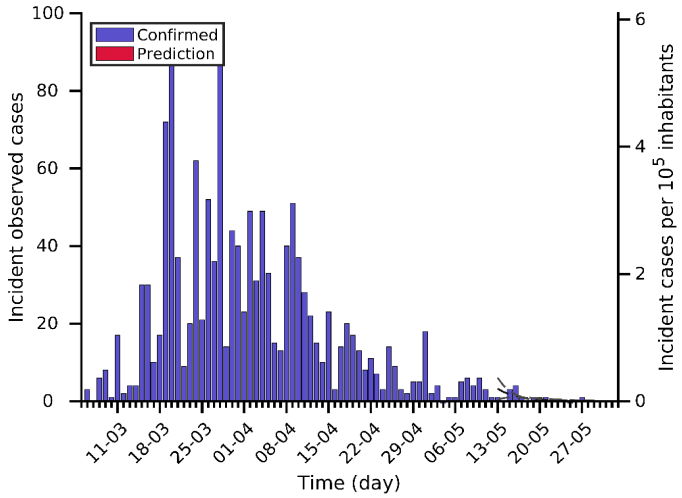
| Day | Number of cases | Interval |
|---|---|---|
| 28-05-2020 | 1355 (+0) | [ 1355 - 1362 ] |
| 29-05-2020 | 1355 (+0) | [ 1355 - 1362 ] |
| 30-05-2020 | 1355 (+0) | [ 1355 - 1362 ] |

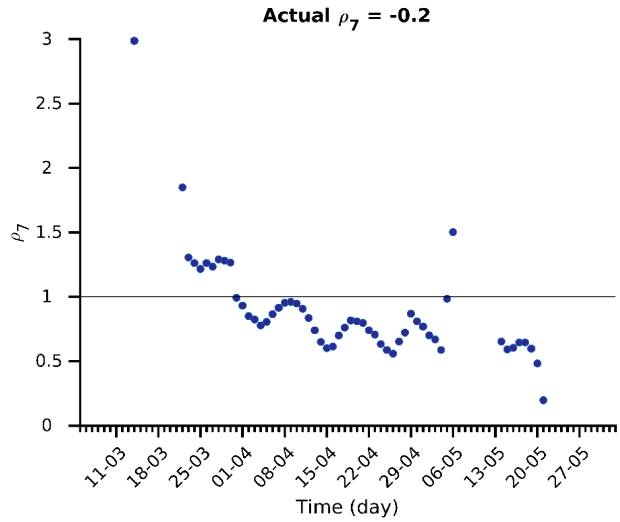


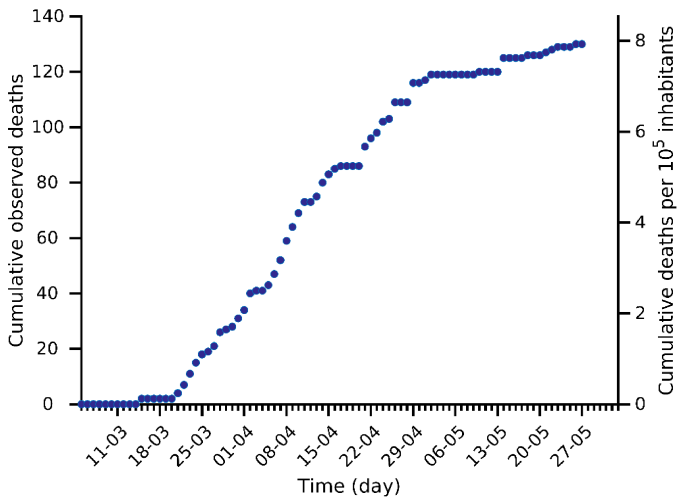



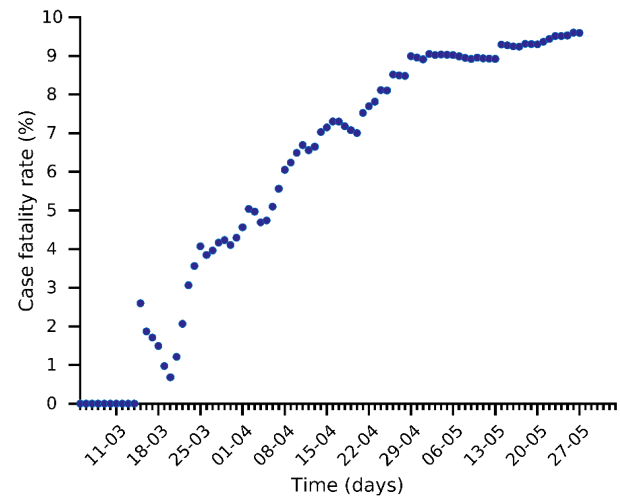



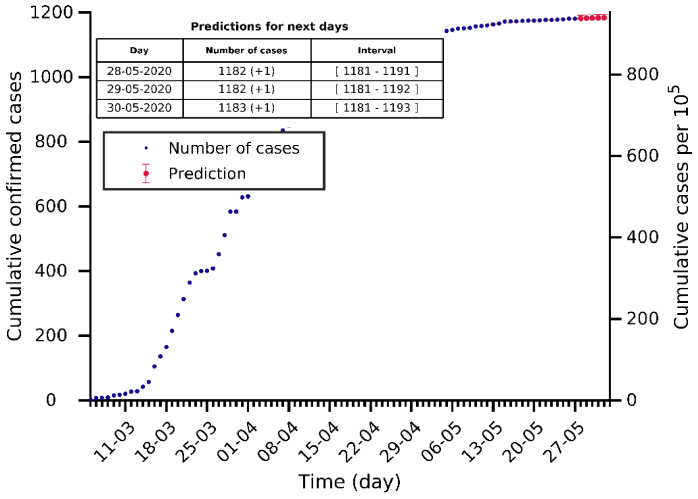



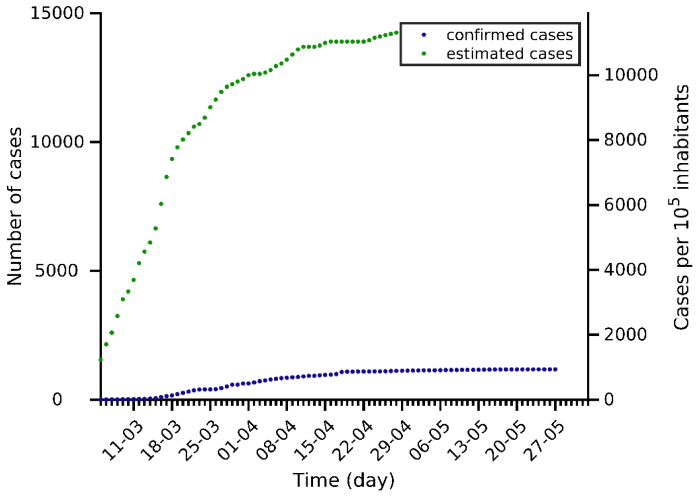



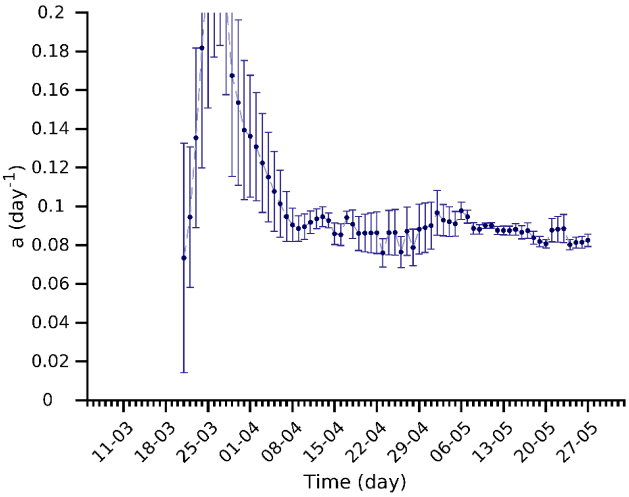



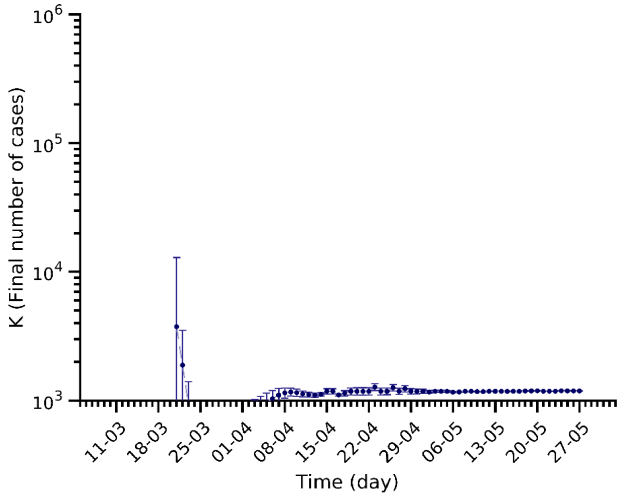



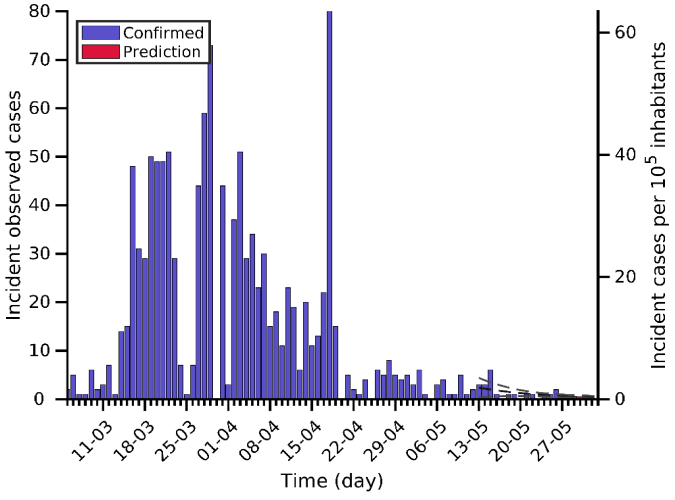
# Valle dAosta  27-05-2020. Population: 0.1M. Current cumulated incidence: 937/$10^5$

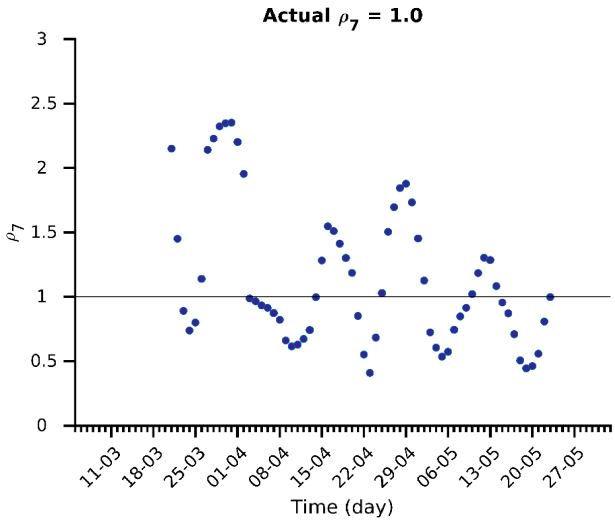


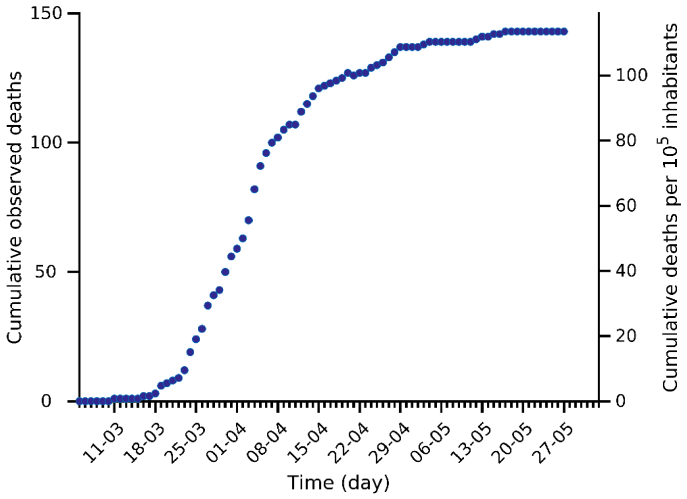



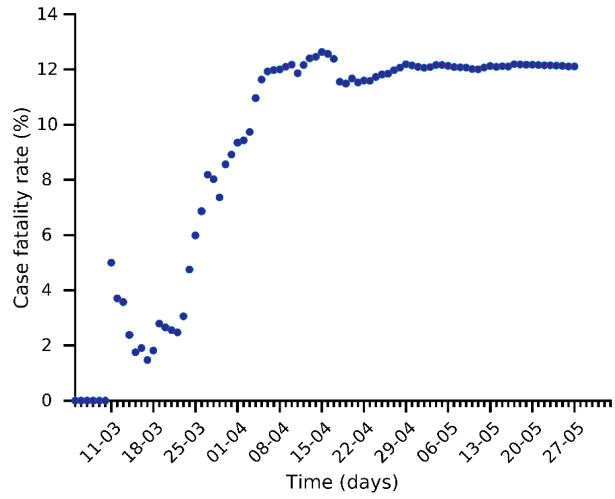



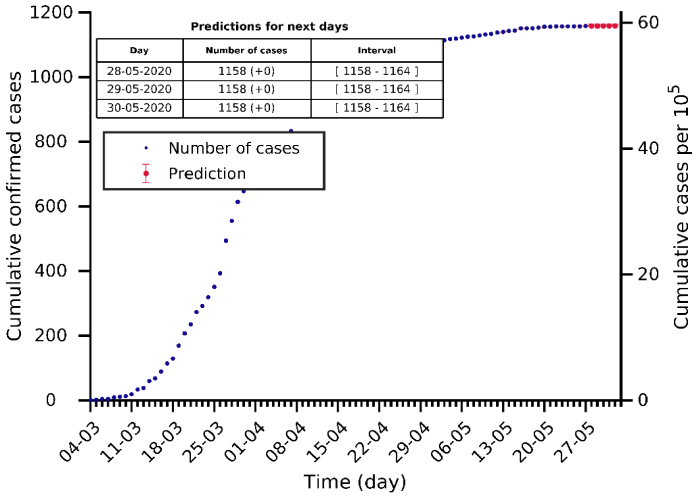



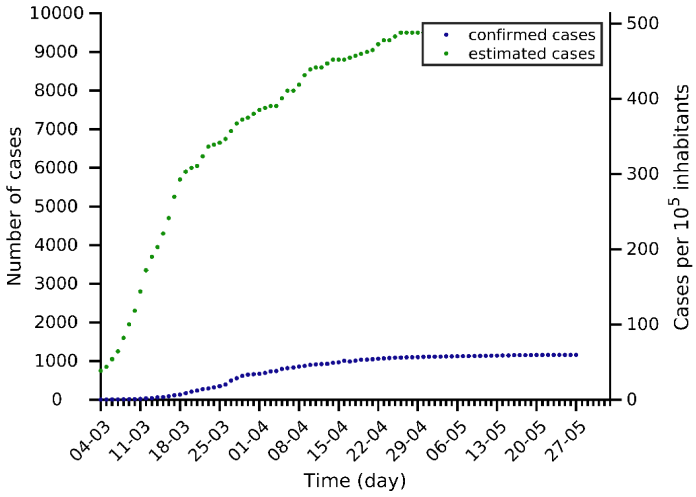



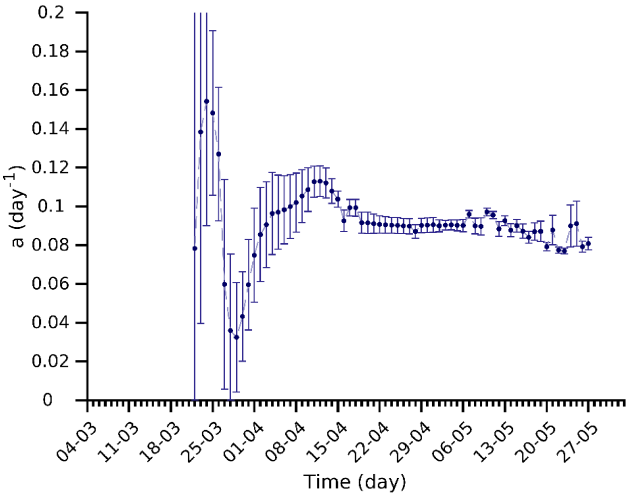



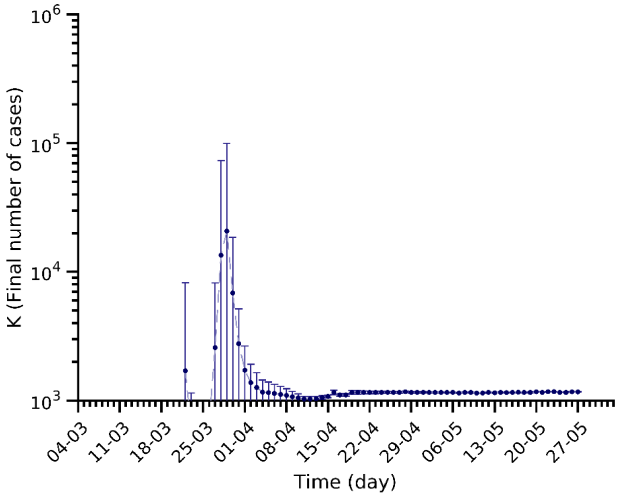



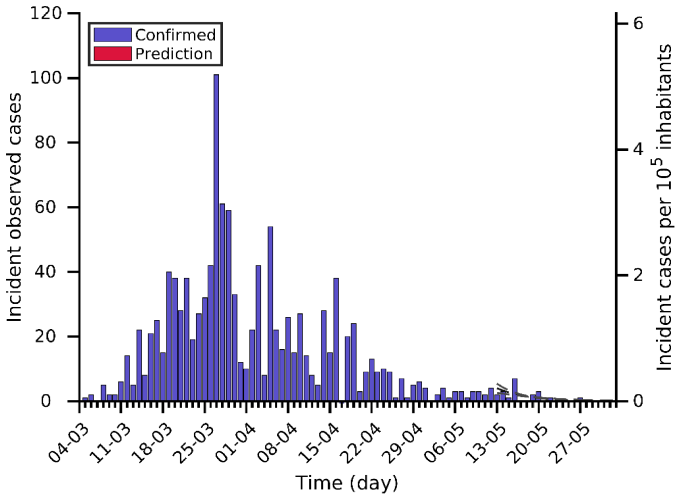
# Calabria 27-05-2020. Population: 1.9M. Current cumulated incidence: 59/$10^5$

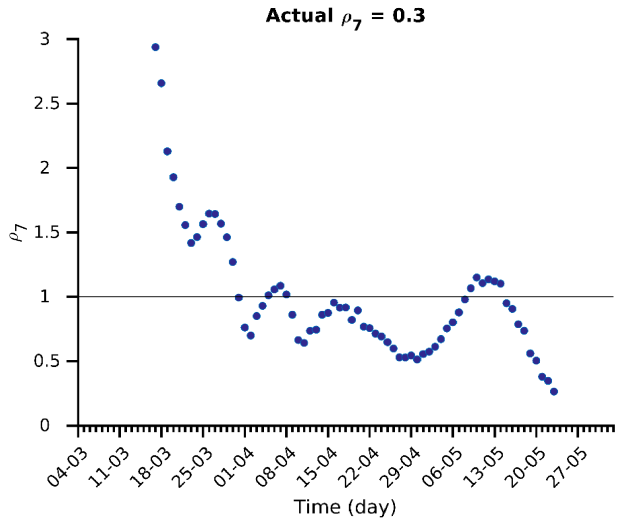


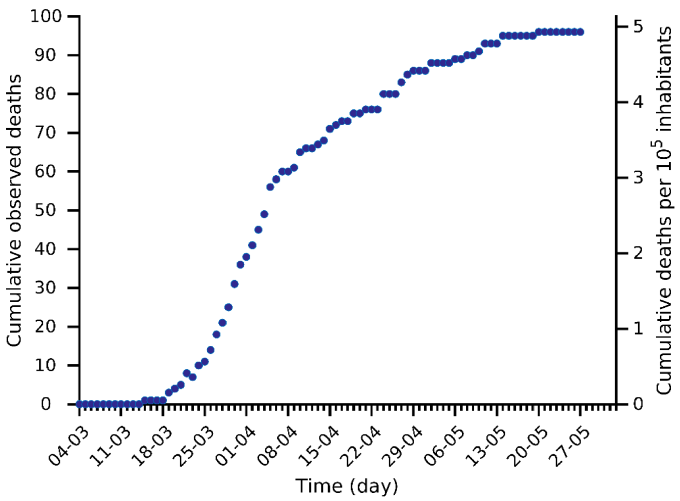



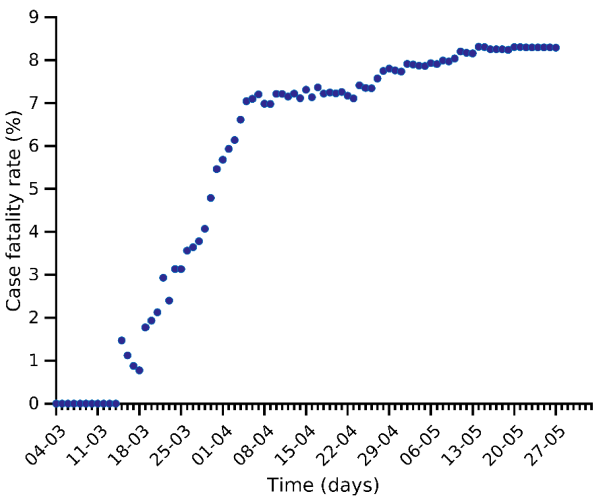



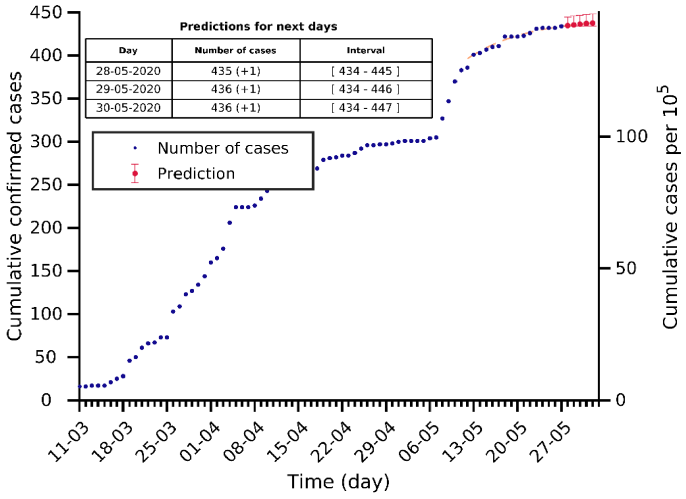



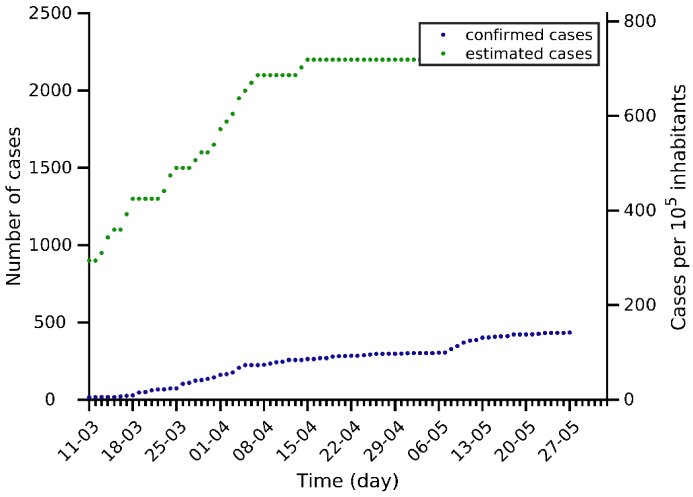



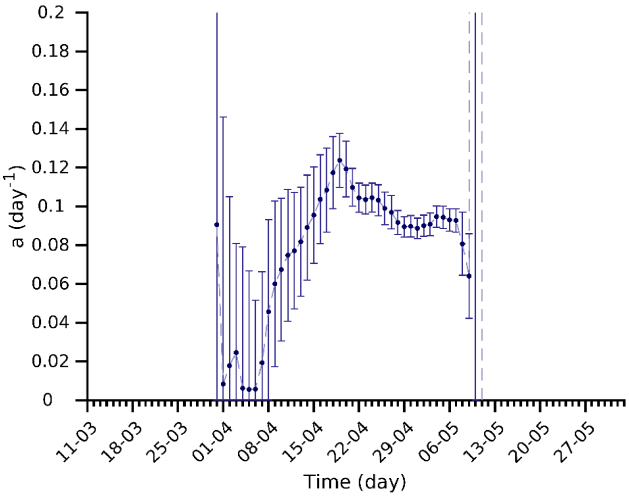



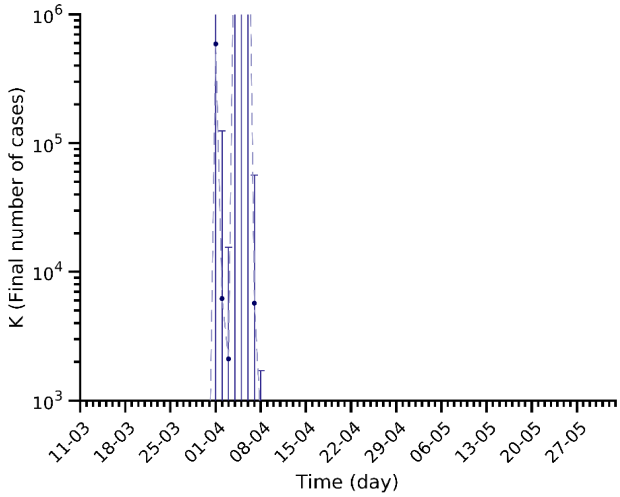



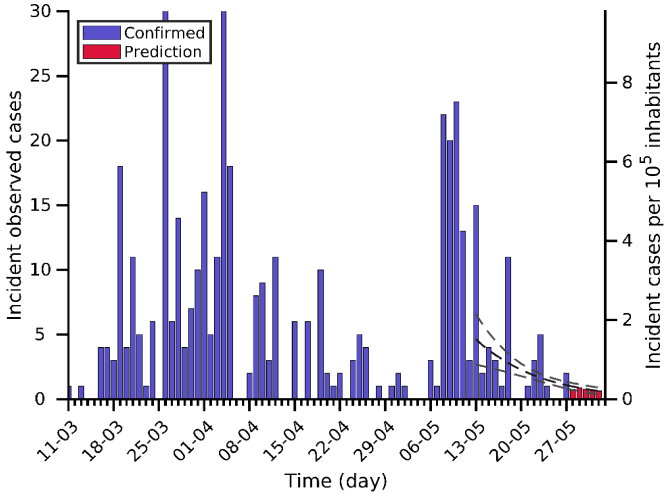
# Molise 27-05-2020. Population: 0.3M. Current cumulated incidence: 142/10⁵

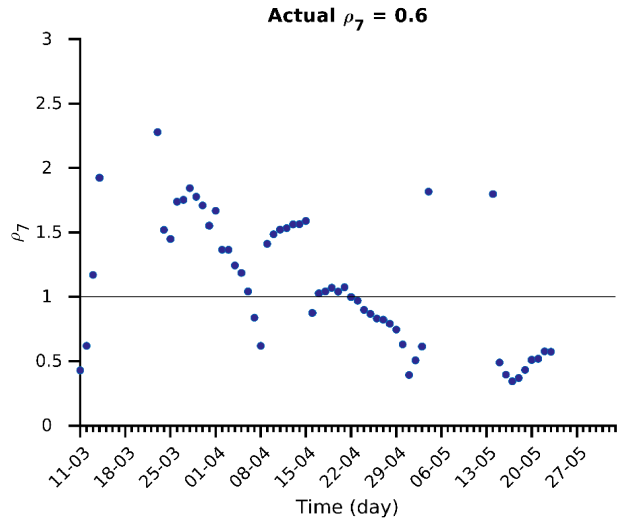


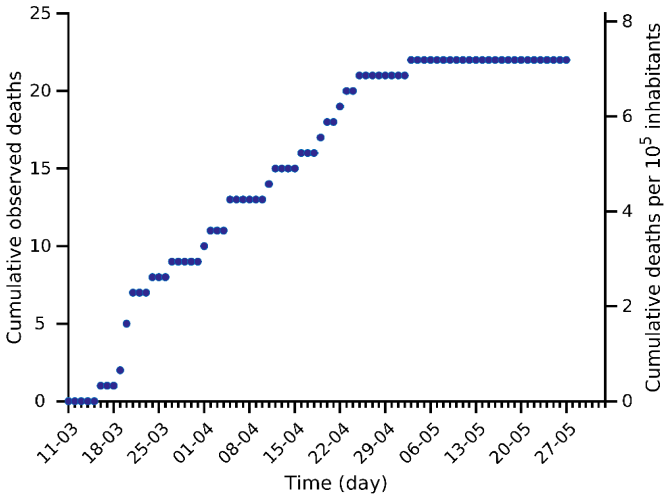



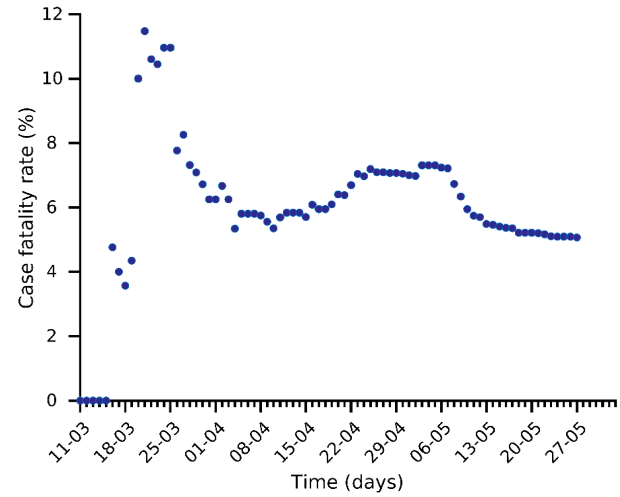



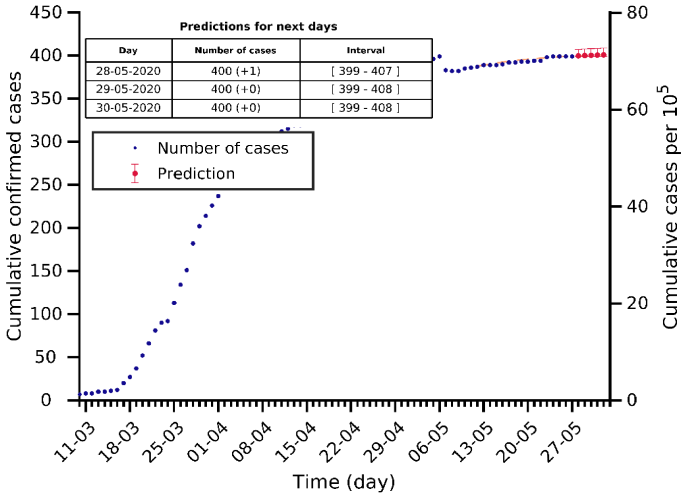



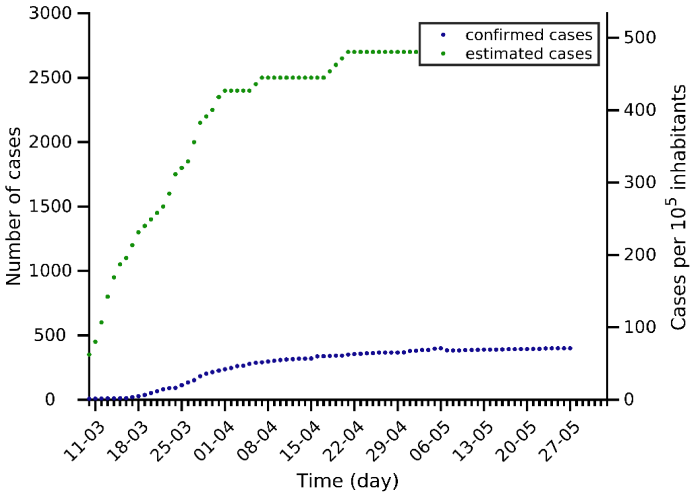



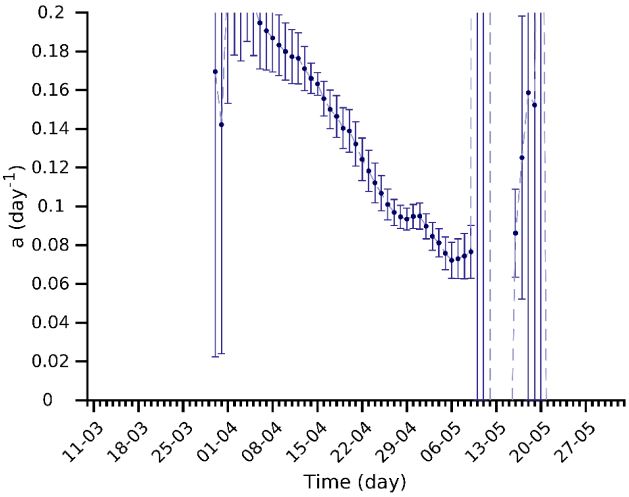



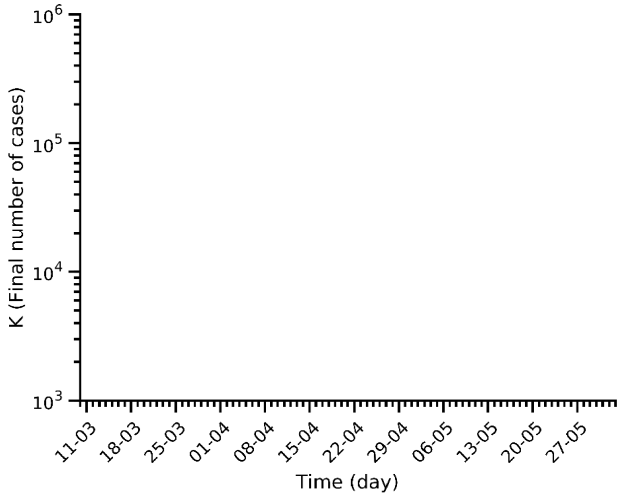



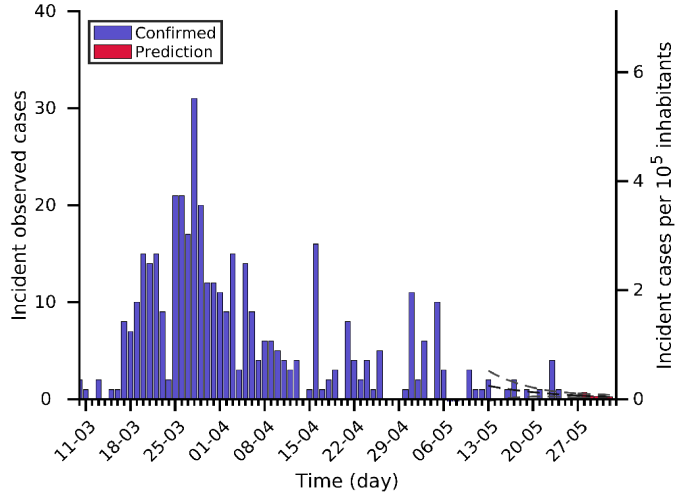
# Basilicata 27-05-2020. Population: 0.6M. Current cumulated incidence: 71/10$^5$

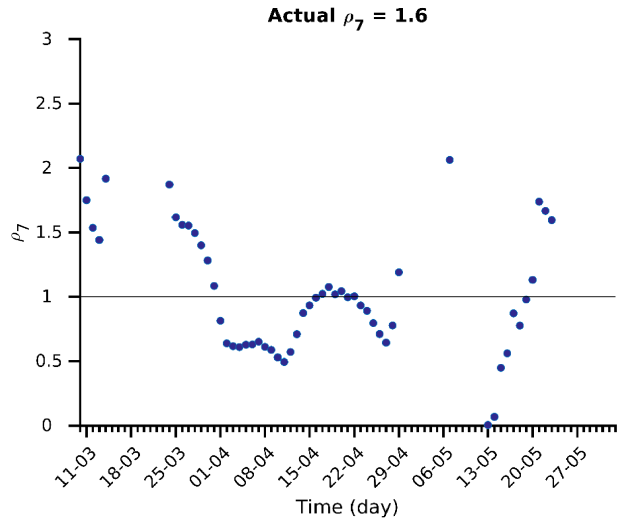


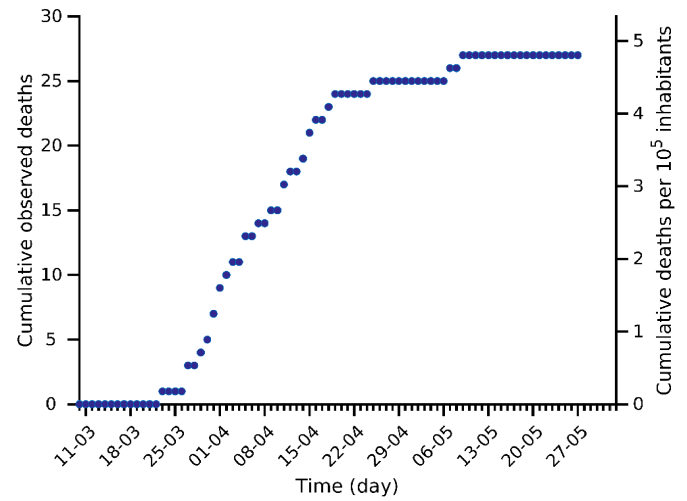



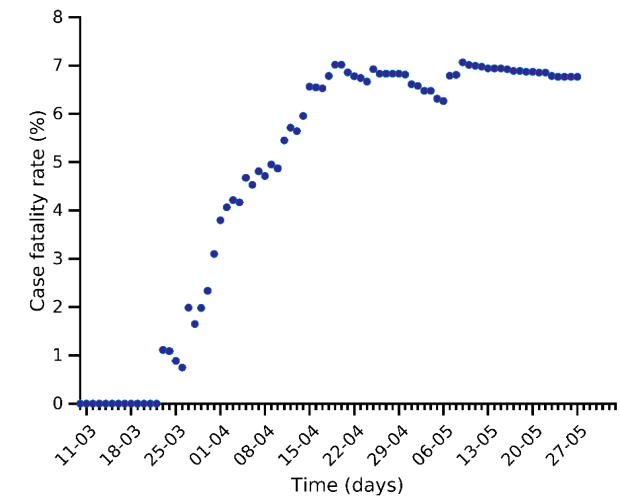



# Methods

## Methods

### *(1) Data source*

Data are daily obtained from World Health Organization (WHO) surveillance reports[2], from European Centre for Disease Prevention and Control (ECDC)[3] and from Ministerio de Sanidad[4]. These reports are converted into text files that can be processed for subsequent analysis. Daily data comprise, among others: total confirmed cases, total confirmed new cases, total deaths, total new deaths. It must be considered that the report is always providing data from previous day. In the document we use the date at which the datapoint is assumed to belong, i.e., report from 15/03/2020 is giving data from 14/03/2020, the latter being used in the subsequent analysis.

### *(2) Data processing and plotting*

Data are initially processed with Matlab in order to update timeseries, i.e., last datapoints are added to historical sequences. These timeseries are plotted for EU individual countries and for the UE as a whole:

- ✓ Number of cumulated confirmed cases, in blue dots
- ✓ Number of reported new cases
- ✓ Number of cumulated deaths

Then, two indicators are calculated and plotted, too:

- ✓ Number of cumulated deaths divided by the number of cumulated confirmed cases, and reported as a percentage; it is an indirect indicator of the diagnostic level.
- ✓ ρ: this variable is related with the reproduction number, i.e., with the number of new infections caused by a single case. It is evaluated as follows for the day before last report (*t-1*):

$$\rho(t-1) = \frac{N_{new}(t) + N_{new}(t-1) + N_{new}(t-2)}{N_{new}(t-5) + N_{new}(t-6) + N_{new}(t-7)}$$

where $N_{new}(t)$ is the number of new confirmed cases at day *t*.

### *(3) Classification of countries according to their status in the epidemic cycle*

The evolution of confirmed cases shows a biphasic behaviour:

(I) an initial period where most of the cases are imported;
(II) a subsequent period where most of new cases occur because of local transmission.

Once in the stage II, mathematical models can be used to track evolutions and predict tendencies. Focusing on countries that are on stage II, we classify them in three groups:

- Group A: countries that have reported more than 100 cumulated cases for 10 consecutive days or more;
- Group B: countries that have reported more than 100 cumulated cases for 7 to 9 consecutive days;
- Group C: countries that have reported more than 100 cumulated cases for 4 to 6 days.

[2] https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
[3] https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases
[4] https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov-China/situacionActual.htm https://github.com/datadista/datasets/tree/master/COVID%2019 , https://covid19.isciii.es/

### *(4) Fitting a mathematical model to data*

Previous studies have shown that Gompertz model[5] correctly describes the Covid-19 epidemic in all analysed countries. It is an empirical model that starts with an exponential growth but that gradually decreases its specific growth rate. Therefore, it is adequate for describing an epidemic that is characterized by an initial exponential growth but a progressive decrease in spreading velocity provided that appropriate control measures are applied.

Gompertz model is described by the equation:

$$N(t) = K\, e^{-ln\left(\frac{K}{N_0}\right)\cdot e^{-a\cdot(t-t_0)}}$$

where *N(t)* is the cumulated number of confirmed cases at *t* (in days), and $N_0$ is the number of cumulated cases the day at day $t_0$. The model has two parameters:

- ✓ *a* is the velocity at which specific spreading rate is slowing down;
- ✓ *K* is the expected final number of cumulated cases at the end of the epidemic.

This model is fitted to reported cumulated cases of the UE and of countries in stage II that accomplish two criteria: 4 or more consecutive days with more than 100 cumulated cases, and at least one datapoint over 200 cases. Day $t_0$ is chosen as that one at which *N(t)* overpasses 100 cases. If more than 15 datapoints that accomplish the stated criteria are available, only the last 15 points are used. The fitting is done using Matlab's Curve Fitting package with Nonlinear Least Squares method, which also provides confidence intervals of fitted parameters (*a* and *K*) and the $R^2$ of the fitting. At the initial stages the dynamics is exponential and *K* cannot be correctly evaluated. In fact, at this stage the most relevant parameter is *a*. Fitted curves are incorporated to plots of cumulative reported cases with a dashed line. Once a new fitting is done, two plots are added to the country report:

- ✓ Evolution of fitted *a* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out;
- ✓ Evolution of fitted *K* with its error bars, i.e., values obtained on the fitting each day that the analysis has been carried out; if lower error bar indicates a value that is lower than current number of cases, the error bar is truncated.

These plots illustrate the increase in fittings' confidence, as fitted values progressively stabilize around a certain value and error bars get smaller when the number of datapoints increases. In fact, in the case of countries, they are discarded and set as "Not enough data" if $a>0.2\ day^{-1}$, if $K>10^6$ or if the error in K overpasses $10^6$.

It is worth to mention that the simplicity of this model and the lack of previous assumptions about the Covid-19 behaviour make it appropriate for universal use, i.e., it can be fitted to any country independently of its socioeconomic context and control strategy. Then, the model is capable of quantifying the observed dynamics in an objective and standard manner and predicting short-term tendencies.

### *(5) Using the model for predicting short-term tendencies*

The model is finally used for a short-term prediction of the evolution of the cumulated number of cases. The predictions increase their reliability with the number of datapoints used in the fitting. Therefore, we consider three levels of prediction, depending on the country:

[5] Madden LV. Quantification of disease progression. Protection Ecology 1980; **2**: 159-176.

- Group A: prediction of expected cumulated cases for the following 3-5 days[6];
- Group B: prediction of expected cumulated cases for the following 2 days;
- Group C: prediction of expected cumulated cases for the following day.

The confidence interval of predictions is assessed with the Matlab function `predint`, with a 99% confidence level. These predictions are shown in the plots as red dots with corresponding error bars, and also gathered in the attached table. For series longer than 9 timepoints, last 3 points are weighted in the fitting so that changes in tendencies are well captured by the model.

### *(6) Estimating non-diagnosed cases*

Lethality of Covid-19 has been estimated at around 1 % for Republic of Korea and the Diamond Princess cruise. Besides, median duration of viral shedding after Covid-19 onset has been estimated at 18.5 days for non-survivors[7] in a retrospective study in Wuhan. These data allow for an estimation of total number of cases, considering that the number of deaths at certain moment should be about 1 % of total cases 18.5 days before. This is valid for estimating cases of countries at stage II, since in stage I the deaths would be mostly due to the incidence at the country from which they were imported. We establish a threshold of 50 reported cases before starting this estimation.

Reported deaths are passed through a moving average filter of 5 points in order to smooth tendencies. Then, the corresponding number of cases is found assuming the 1 % lethality. Finally, these cases are distributed between 18 and 19 days before each one.

[6] At this moment we are testing predictions at 4 days for countries with more than 100 cumulated cases for 13-15 consecutive days, and 5 days for 16 or more days.

[7] Zhou et al., 2020. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The Lancet; March 9, doi: 10.1016/S0140-6736(20)30566-3